PROCEEDINGS

OF THE

ENGINEERS' CLUB

OF

PHILADELPHIA.

ORGANIZED, 1877.

VOL. XI.

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ENGINEERS' CLUB OF PHILADELPHIA

ORGANIZED DECEMBER 17, 1877.

NOTE.—The Club, as a body, is not responsible for the statements and opinions advanced in its publications.

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I.

A DISCUSSION OF THE RIVETING PRESSURES REQUIRED FOR BRIDGE AND BOILER WORK.

November 18 *and December* 2, 1893.

MR. WILFRED LEWIS:—This subject has been selected for general discussion for its practical interest and the lack of definite information to be found concerning it.

Until quite recently, certainly within the last decade, the manufacturers of riveting machines met with little if any demand for a pressure exceeding 60,000 pounds, but now, pressures as high as 150,000 pounds are not uncommon, and even 300,000 pounds is occasionally required. The necessity for heavier pressures had apparently arisen in boiler work, with the thicker plates required for increasing steam pressures, while in bridge work the advance was not so marked. Considerable diversity of opinion seemed to exist upon the pressure per square inch of rivet section required for either class of work, and it was hoped some light might be derived by an interchange of views among men of knowledge and experience upon this important question. It was also suggested that information in regard to the value of a plate closer in riveting would be in order.

A number of letters have been received from members unable to be present, expressing interest in the subject, and in one of them Mr. David Townsend called attention to some samples of rivets manufactured by Phillips and Townsend, which are distributed among the members.

It is claimed for these rivets that the quality is such as to admit of cold driving, but it is not contended by Mr. Townsend that the best results were to be expected by driving in that way. In regard to the pressures required for driving rivets cold, I would recall some experiments made by Wm. Sellers & Co., Incorporated, between the compression platforms of their Emery testing machine. A number of $\frac{3}{8}$-inch rivets were subjected to pressures between 10,000 and 60,000 pounds. At 10,000 pounds the rivet swelled and filled the hole without forming a head. At 20,000 pounds the head was formed and the plates were slightly pinched. At 30,000 pounds the rivet was well set. At 40,000 pounds the metal in the plate surrounding the rivet began to stretch, and the stretching became more and more apparent as the pressure was increased to 50,000 and 60,000 pounds. From these experiments, the conclusion might be drawn that the pressure required for cold riveting was about 300,000 pounds per square inch of rivet section.

Mr. James Christie:—During recent years, the importance of having rivets completely fill the holes has been more fully realized than heretofore. Under the system of hand-riveting—as usually practiced formerly—doubtless much imperfect work was done, and it was a fruitful source of disaster, as rivets with loose-fitting bodies are not only imperfect in themselves, but they allow undue weakness in the plates, owing to incomplete bearing surface. Hence, the strongest joint has been found, by experiment, to be that in which the area of rivet body exceeds the net sectional area of plates, the increased bearing surface and grip of heads more than compensating for a reduced plate area.

When riveted joints are being formed, the tendency is for the rivet to upset, first, at the end where the final head is being upset, the friction of the metal in the hole resisting its flow to some extent.

The tendency will be for the rivet to fill completely at the one

end, and less perfectly at the end next the original head. It would, therefore, conduce to sound work, if straight blanks were used, and both heads upset simultaneously at the closing operation.

It is now good practice to form the rivet blank with an elongated head, having considerable excess of metal, this excess being forced into the hole when the rivet is driven. The amount of pressure required to upset rivets properly depends not only on the heat of the rivets and kind of material, but also on the length of rivet, as the frictional resistance to flow increases with the length of hole. The dimension of rivet-head also is a factor in the question, as the final compression is distributed over the area of the head.

It has been found that for rivets of iron, or very soft steel, a pressure of fifty tons per square inch of sectional area of rivet is sufficient to completely fill the hole, providing the rivet is of moderate length—say the length of grip not exceeding three diameters—and the rivets worked at a bright red heat.

For rapid work, it is frequently necessary to drive rivets, after they have become much reduced in temperature, and, especially if rivets are of unusual length, a higher pressure is desirable, even to double the pressure. In fact, it is the best practice to drive rivets at a low red heat, and use correspondingly higher pressure on them; as, if rivets are worked too hot, and the pressure instantly withdrawn, especially if the joints do not naturally lie in close contact, there is an opportunity for the spring of the plate to stretch the overhot rivet, and open the joint and loosen the rivet. It is, therefore, sometimes found desirable to maintain the pressure on the rivet for a brief interval, until its temperature is somewhat reduced.

The type of machine in which the rivet is compressed would not seem to have a very direct bearing on the subject, providing it is so designed that compression can be maintained to finality with certainty.

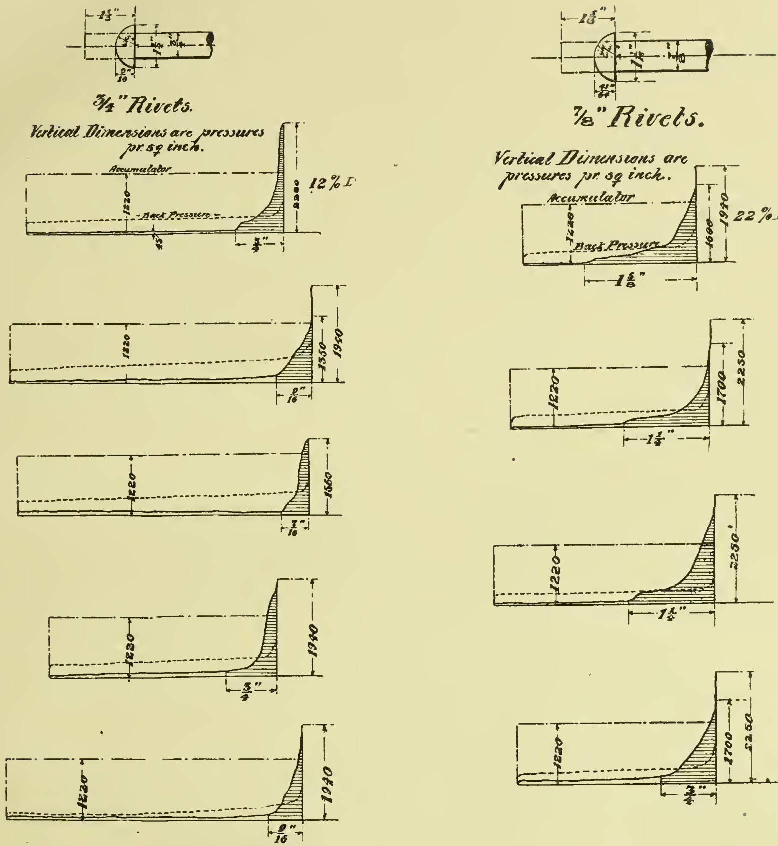
The direct hydraulic ram has the advantage of compactness and general simplicity, and if the fluid is stored in an accumulator, it offers the great advantage of a final, sharp compression, when motion is terminating, due to the arrest of the mass of the

accumulator. A static pressure of 1,200 pounds per square inch, in an accumulator, has shown on the gauge a momentary impact of 2,000 pounds per square inch at each termination of stroke, a condition especially favorable to rivet compression.

The plate-closing attachment is not used to any extent on structural work, principally because its application is usually impracticable; rivets have to be driven so close to projections and corners, that it is frequently troublesome to obtain sufficient room for the necessary tools, without considering plate-closing auxiliaries. Its need is not felt on girder work, as curved work is exceptional, and in first-class work all material is so accurately straightened before assembling, that it is readily brought together by the action of upsetting the rivet. Any tendency to separate, which cannot be prevented by the rivet itself, is not apt to be benefited by previous plate-closing.

The quantity of work, capable of being done in a definite time, varies very much, according to contingencies, which embarrass, more or less, the free progress of the workmen. With plain girder work, and an equipment for ready handling of material, a rivet gang of three men, and a boy to heat, can drive, on an average, 5,000 ordinary rivets, $\frac{3}{4}$ or $\frac{7}{8}$, per day of ten hours, or about 3,000 rivets per day, with the average run of work used in bridges. There is a record of 10,000 rivets having been driven by a gang in ten hours. This was done for a wager, on very plain work. The work was done with a direct steam riveter, and of course only shows what work is possible, not what can be continuously performed.

Mr. Henrik V. Loss:—I submit some remarks and data, all pertaining to bridge riveting, in connection with some indicator cards of steel rivets taken by me from a bridge riveter at the Pencoyd Bridge Works, a couple of years ago. They were all taken by a common steam indicator in connection with a pressure-reducing cylinder, and show the pressures existing at different parts of the stroke. The cards, while few in number, show nevertheless the great variation in pressures existing with any one dimension of rivet, amounting to about 50 per cent. for the $\frac{3}{4}$-inch rivets and 25 per cent. for the larger ones. Under such conditions it is almost useless to try to formulate



definite rules for the necessary power to do the work, as the average itself for any one size will require such a very large margin to cover the extreme cases. If, however, the average *be* introduced it is seen when comparing the two sizes, that this average pressure amounts to the same, or about 1,800 pounds per square inch on a 10-inch cylinder, which, when subtracting the pullback, gives 65 tons for either $\frac{3}{4}$-inch or $\frac{7}{8}$-inch rivet. Now, does this mean that a large rivet takes no more power than a smaller one? If such is the case inside of certain limits, I should not be at all surprised. Of course, only within certain limits, above which it would take more, and for less than which it would take a smaller amount. That in many cases of upsetting a

smaller dimension requires greater power than a larger one, is a positive fact. In the case of eye-bars, or rounds and squares for bridge purposes, experiments have conclusively shown that, inside of certain limits and dimensions, a smaller bar requires more, at least not less, power than a larger one. This is due to the rapid cooling effect of the surrounding cold dies upon the heated inserted bar. It is very possible that a similar condition of affairs exists with the rivet, when inserted into and surrounded by the cold plates. If it is large enough to hold the heat it may, if not too large, offer less resistance than a smaller rivet, which has been considerably cooled down.

Referring to the above figure of sixty-five tons, this is the pressure existing when the stroke is finished and the head is done. For bridge riveting this is generally sufficient, or if not, only very little more is wanted to make a rivet that will stay tight and not rattle loose. For boiler work, however, a greater margin is necessary, and $\frac{3}{4}$-inch or $\frac{7}{8}$-inch rivets would, with grips as great as those prevailing in bridge work, require at least seventy-five to eighty tons. But the grips with boiler work are generally much smaller than with bridge work, and a pressure of sixty-five tons for the above dimensions will be sufficient for the ordinary boiler plates and pressures. Speaking in a general way about the pressures necessary to upset a rivet, this depends not only upon its temperature and diameter, but also upon the relation between diameter and length and upon the character of the rivet hole. The better the hole, the less the power. The fewer the obstructions offered to the sliding of the metal in the hole, while under pressure, the less power it will take to make it slide. But when speaking of long rivets, which are the ones that for the same diameter require the largest exertions, it can readily be supposed, that to each length there is a corresponding diameter, which gives the smallest resistance per square inch of metal. Above this diameter the column becomes too strong, while below it, it becomes too weak, in which latter case it bends and bears against one side of the hole with great force, and the subsequent upsetting jams the metal in the line of least resistance, forcing it to slide along the side of the hole and filling the far end, near the first head, only with great difficulty and under

great pressure. Upsetting a short rivet is a fair test of the strength of the metal, and well-defined rules can no doubt be laid down, governing the power according to the diameters; but with large lengths it becomes almost impossible, as already explained. This is corroborated and shown by the great irregularities of the power lines on the accompanying cards.

As to the energy consumed, the figures are more definite, as the variations are not so great.

A $\frac{3}{4}$-inch rivet takes about 7,200 foot pounds to form a head and fill the hole, while a $\frac{7}{8}$-inch rivet requires 9,500 foot pounds to do the same work, or about in the proportion as the squares of the diameters. That this relation holds good for other dimensions, further experiments will have to show. It corresponds, however, exactly with the material displaced in each case. Referring to "The Pencoyd Standard of Rivets," we find the displacements for $\frac{3}{4}$-inch rivets to be .39 cubic inch; and for $\frac{7}{8}$-inch rivet, .525 cubic inch; which figures are seen to follow closely as the squares of the diameters. It is thus observed, what also on first thought seems very natural, that the energy in foot pounds necessary to upset a rivet, and the displacement of the metal in the rivet due to the upsetting, go hand in hand.

The cards also show the great loss of energy, in the ordinary riveters. Efficiencies of 12 per cent. and 22 per cent., the latter being the maximum, are figures that would not be tolerated in anything but hydraulic machinery. In a riveter, which I have lately gotten ready to place on the market, this feature has been overcome and economy secured. As this, however, does not strictly pertain to the subject in hand, I will leave the detailed study of the indicator cards and all that this involves to some future meeting.

Mr. F. H. Lewis:—I am not prepared to talk about the power required in riveting machines, having never had occasion to investigate this part of the subject, but, from a large experience with the results obtained from riveting machines, I have seldom seen reason to think the power was excessive, except occasionally in air riveters.

It is rather difficult to understand how powerful riveting machines can drive loose rivets, yet all of them do so occasionally.

Probably this is due to a powerful buckle which has been put into the work in bolting up, and which acts to loosen the rivet after the pressure is released.

Of the three classes of riveters—steam, air and hydraulic machines—I decidedly prefer the hydraulic riveter, whenever it is practicable to use it. The steam riveter depends directly upon the boiler pressure and on the satisfactory transmission of that pressure to the machine. My experience is that the work done by these riveters is not reliable, and that you are quite sure of finding a greater or less percentage of loose rivets in all the work they do. The air riveter is much more reliable for cylinder pressure than a steam riveter. The air is compressed by an automatic steam-engine, whose steam cylinders are large enough to act properly, even if the steam pressure does fall. The piston of an air riveter works, however, on a toggle joint, which must be nicely adjusted to the thickness of the section riveted in order to do good work. If the lever falls short, the pressure is light, if the lever is too long, the force exerted is excessive. I have seen instances in which an air riveter had actually bedded the rivet head a thirty-second of an inch or more in the cold metal.

The hydraulic riveter is simple, direct, reliable in power and pressure, and its work meets with more general approval.

Mr. S. M. Vauclain stated that a very important point to be considered is the condition of the rivet itself before being driven. It should be at exactly the right temperature, and this is difficult to determine, except by repeated trials.

With iron rivets and poorly made holes he has found in boiler work that it does not take a very heavy pressure to fill the holes, provided the rivets have been properly heated. To make a close joint they should be hotter under the head than at the end, and if they are equally heated the ends may be cooled by dipping them in water immediately before inserting them in the plates. The rivet-boys soon become skillful in this matter, and accomplish their purpose, usually, by placing the rivet in the fire with the head down and the end sticking up.

A series of tests were made by him at the Baldwin Locomotive Works, to determine the best pressures for driving the various sizes of rivets. Six sets of plates were taken, each set made up

of six plates $\frac{9}{16}$ inch thick, and drilled with holes varying by $\frac{1}{8}$ inch from $\frac{5}{8}$ inch to $1\frac{1}{4}$ inch. In the first set all the rivets were driven with a pressure of 25 tons; in the second, 33 tons; in the third, 50 tons; in the fourth, 66 tons; in the fifth, 75 tons; and in the last, 100 tons. The riveted specimens were then cut in half longitudinally through the rivets, and they showed that when a pressure of 33 tons had been applied, the metal under and around the two heads of the $\frac{5}{8}$-inch rivet was indented or compressed; where 50 tons had been used, both the $\frac{5}{8}$ and $\frac{3}{4}$-inch rivets showed the same effect, and so on up to 100 tons, which caused an indentation more or less perceptible under all the heads except those of the $1\frac{1}{4}$-inch rivet.

In another case a set of plates was taken and treated in a similar manner, except that the holes were punched and the pressure graded from 25 tons for the $\frac{5}{8}$-inch rivet to 100 tons for the $1\frac{1}{4}$. There was no visible indentation in this case, and the rivets all filled the holes; the conclusion being that the suitable pressure for a $\frac{5}{8}$-inch rivet is 25 tons; for $\frac{3}{4}$-inch, 33 tons; for $\frac{7}{8}$-inch, 50 tons; for 1-inch, 66 tons; for $1\frac{1}{8}$-inch, 75 tons; and for $1\frac{1}{4}$-inch, 100 tons. These figures, it will be noticed, are in a very convenient shape for practical use. On reducing them to pounds per square inch of rivet section, quite a satisfactory agreement between them appears, as in the following table:

Rivet	$\frac{5}{8}$ inch.	$\frac{3}{4}$ inch.	$\frac{7}{8}$ inch.	1 inch.	$1\frac{1}{8}$ inch.	$1\frac{1}{4}$ inch.
Pounds per square inch	162,900	149,400	166,300	168,100	150,900	163,000

The average of these is 160,100 pounds per square inch of rivet section, which may be of use in calculating the necessary pressure for rivets of other sizes.

An experiment was made also in cold riveting. Six $\frac{3}{4}$-inch rivets were driven cold into a pair of plates with punched holes, using the same range of pressure as before, but it was found that the lower pressures were not sufficient to form a head, whereas the higher ones indented the plates.

A number of the samples were etched with dilute acid and developed some very interesting fibre studies.

Mr. John T. Boyd:—I am in favor of hydraulic riveting wherever it can be used; and where there is not an absolute cer-

tainty that the riveting machine without a plate-closer will drive rivets and make *tight work* with a minimum amount of caulking, a plate-closer should be used.

I favor an accumulator, in which the weights can be dropped, and thereby limit the pressure that can be applied to the rivets when working on plates of varying thickness, and I am not in favor of an accumulator which furnishes a uniform pressure for all classes of work.

I am well aware that literature on the subject of riveting is very meagre, and, unless manufacturers will assist in giving the results of their experience, I do not know how the literature is to be obtained.

In regard to the pressure used, I have seen most excellent results obtained where the pressure did not exceed 20,000 pounds per square inch of area covered by the head of the rivet when formed, and you will observe that, in this case, the diameter of the *head* of the rivet has necessarily more to do with the case than the diameter of the *body* of the rivet.

I am aware that higher pressures than the foregoing are used, but I believe that the *make of the rivets* and the thickness of the plates would have to be taken into account to secure the most satisfactory results. The latter I take to be tight work without cracking or destroying the sheets by buckling or flattening under pressure.

If an oil or a gas furnace is used to heat the rivets, the pressure to drive the proper-sized rivet for a given thickness of plate can be determined with great nicety; but where rivets are heated in a coke or coal fire, some are liable to attain a greater heat than others, and imperfect riveting of anything but a uniform character would be the result.

I always work from the basis which I have given you here and have not made any failures where I was able to control the conditions. I do not for a moment wish to say that my ideas are infallible, but give you what has been the result of my experience in this direction.

I have never had to operate a machine with a plate-closer, but I believe that the latter is a very excellent feature to have when you are working on thick plates, or if, for any reason, you are unable to maintain a high pressure sufficient to do tight work

without it; such, for instance, as a leak occurring in the packing of the pumps, or around the ram of the accumulator, or a slight leak in the pipe under ground.

These unpleasant occurrences have to be looked for, and I, therefore, differ with those who believe that the plate-closer should not be applied to a machine where the total pressure upon stake, or the riveting dies, is less than one hundred tons.

MR. E. A. W. JEFFERIES, Visitor:—The intended point of my remarks is to convey an accurate idea of what constitutes a correct use of the plate-closing riveter. As ordinarily built, the operator is at liberty to make or mar the result as he pleases. A too early transference of the plate pressure to the rivet results in "washering" between the plates when they are thick. If, on the contrary, the transference is delayed for some moments after the proper time, then the rivet does not get the full effect of the force of the machine—in fact, only about *half* of it, and this latter is what almost invariably occurs, so that plate-closing riveters have in the past been frequently condemned as not doing good work, whereas the fault lies wholly with the operator. However, the operator needs to be extremely alert and attentive to every rivet he drives in order to get the desired result. Hence, from this arises the necessity for an *automatic device* to transfer the plate pressure to the rivet at the proper moment.

There has been only *one* such machine designed and built. It was shown in operation at the exhibit of Messrs. R. D. Wood & Co., in Chicago.

MR. HENRIK V. LOSS:—I would say, in reply to Mr. Vauclain, that while apparently the figures as given by him do not agree with the indicator results, as far as pressures are concerned, it must nevertheless be remembered that my cards refer to long rivets and rough holes, while with his experiments the holes were smooth and coincided centrally. I want to emphasize the detrimental effect of a rough hole not so much with a short rivet as with a long one. In the former case, with a short rivet, very little sliding is done, the work being mainly pure upsetting, while with longer ones, especially if the diameter is not very great, the material must inevitably slide considerably, and if the surfaces be rough and uneven, a large increase of power is necessary. It must also be asked whether, in computing the

figures as given by him, he simply took the accumulator pressure as the ordinary pressures in the riveting cylinder. If so, the figures are certainly too small, as the impact of the accumulator weights will always add anywhere from 25 to 50 per cent. to the static pressure at the moment the piston comes to a stop.

Mr. Jefferies speaks about the effect of a plate-closer. Now, speaking generally, as rivet plants are ordinarily constructed, a plate-closer does very little work; and, if it had a separate accumulator, I do not hesitate in saying that whatever effect it does produce might easily be accomplished with a plate-closing cylinder of not more than one-half of its present standard diameter. The reason is simply that while the riveting piston is moving and both cylinders are in close communication, the pressure per square inch throughout them both is simply whatever the resistance of the rivet to upsetting creates. Before the rivet has been met, and before any real upsetting occurs, the existing pressure per square inch in the cylinder is about 45 pounds, or just what the friction of packing, etc., requires. As the resistance increases, so does the water pressure, and all this while the accumulator pressure is ostensibly about 1,200 pounds per square inch. If any good effect is desired, use separate accumulators, or at least have separate pipes for the two cylinders and join them only at considerable distance from the machine. However, with well-fitted holes, I think the plate-closer unnecessary, except for very heavy plates, and even in such cases its effect is overrated, as very little pressure exists in its cylinder until the stroke is finished, at which time it is too late, the damage, if any, being done at the early stage of the upsetting.

Mr. John Birkinbine:—From what has been said it would appear that a most important feature, namely, the quality of iron in the rivets, is often neglected; but in locomotive, in boiler, in bridge and structural work, where many lives are dependent upon the integrity of the structures, it would seem that nothing but the best quality obtainable should be considered as fit for use. Specifications for boiler shells and heads are exacting as to quality, but we seldom find the quality of a rivet or stay-bolt specified. It appears strange to pay almost "fancy prices" for plate iron or steel of known composition or quality and yet connect the parts by rivets or bolts of which we know little or nothing.

These remarks are not to be interpreted as reflecting upon the material used or furnished by any parties to this discussion, but solely as inviting attention to a detail of construction too often overlooked.

Mr. John T. Boyd:—Mr. Birkinbine's allusion to "quality of iron in the rivets" is most pertinent, and is intended to be covered by my statement concerning "make of rivets."

Just now I have in mind one make of rivets which is good anywhere and can safely be called "all-around rivets." These are to be preferred to several other makes if used for snapping, or for hand-driving, said other makes being "at their best" when worked in the machine or "bull," because they will not stand the battering of hand or "snap" driving. The boiler makers have preferences which are sometimes not based on "highly scientific grounds," but the results of their work is what tells in the long run.

If rivets are too hot or unevenly heated, it is difficult to tell what you have accomplished until tested in any one of the well-known ways; and the longer the body of the rivet, the more apparent this becomes. Take, for instance, 14-feet diameter marine boilers for 160 to 180 pounds pressure, built with double butt straps—it requires a long rivet at the curvilinear seams where the butt straps come, and on same seams where the heads are riveted to the shell. This same instance occurs in top flange of long span, heavy traffic, plate girder bridges, and Mr. Vauclain states a fact, often proved, that repeated trials are necessary to determine heat requisite to do the work as it should be done.

As the diameter of rivet is usually determined by thickness of plates, the pressure to drive rivets should be controlled by the quality of the iron in rivet, temperature of rivet, and by the length of the body of rivet between the heads; and, in connection with these, the quality of the plates should be considered, because some grades of plates will split or crack between the holes and edge of plate, and may give way between the holes themselves under excessive pressure, the extent of which a trial alone will tell.

[Note.—In illustrating his remarks, Mr. Vauclain exhibited the complete set of carefully prepared experimental specimens from which his conclusions had been drawn.—Publication Committee]

II.

SOME NOVELTIES IN BEVEL GEARING.

By Max Uhlmann, Visitor.

Read December 2, 1893.

All contrivances for transmitting motion or power can be divided into two classes, viz., those that are *definite* in their action and those that are *indefinite.*

If a belt is running over two pulleys whose diameters are as nearly in the proportion of one to three as they can possibly be made by human skill, and even if no slipping at all occurs, the motion will not be transmitted, as many mechanics would suppose, at that ratio. On account of the necessary thickness of the belt the fibre of that side which is in contact with the pulleys will be compressed, while that of the other side will be expanded. This compression and expansion takes place in a greater degree when the belt is passing around the smaller pulley than when it is passing around the larger, and the same length of belt will not cover as many units of circumference on the former as on the latter. From this it follows that the ratio of motion in the assumed case is a little less than one to three. How much less is theoretically indeterminable on account of the variable nature of belting.

If, now, a belt is running over two pulleys of *equal* diameters, the disturbing factor, just pointed out, does not exist. Yet the velocities of the pulleys are not equal as soon as the belt is required to transmit any power. The belt will then be stretched on its pulling side and will pass around the driving pulley in that condition, while in going around the receiving pulley it will be under comparatively little tension or none at all. This allows a creeping back of the belt, causing the receiving pulley to run slower than the driver. Consequently the definite ratio of motion, which in this case should be one to one, is lost here, too, owing to the flexibility of the transmitting material; and the extent to which this takes place is likewise indeterminable.

Another very great source of variability in belting is the slipping, which likewise is inevitable.

All these difficulties have to be contended with not only in the case of belt-driving, but also in that of rope-driving and of any other similar means of transmission depending entirely on friction. All of these are what is called *indefinite* in their action.

Therefore, when in transmitting power from one part of a mechanism to another a given ratio is to be maintained, some other means must be resorted to, and it is then that toothed gears become indispensable.

Though gears are as liable to accidents as anything else, and may be objectionable on account of their noise, when running at a high speed, yet they are absolutely free from all the above sources of error, as is no other means of transmission even under normal conditions.

The definite ratio of transmission is not, however, the only requirement good gears have to meet. Their teeth must be of such a shape as to transmit the motion with uniform velocity (without jerking) and with as little noise as possible. Defects of this kind make themselves especially felt in pinions with a low number of teeth. To obviate the noise, pinions are made sometimes of vulcanized fibre or rawhide; but while such pinions are very good for many purposes, they wear rapidly when subjected to continual work. Therefore, gears made of more durable material, with teeth of as nearly perfect shape as possible, are still in demand.

The number of possible shapes that would answer is infinite, but only two of them are in actual use. They are the cycloid and the involute. Though the cycloid was in general use at one time, there are strong indications now that it may be superseded by the involute for reasons that will be mentioned later. Scientific mechanics have exercised their ingenuity in an attempt to produce gears with perfect teeth of either of these forms; but although a great deal has been accomplished in this direction, the much desired result, perfectly noiseless gears, of efficiency and durability, has not yet been attained.

The best result so far has been obtained from spiral gears. A right-hand and a left-hand spiral *spur* gear, mounted on shafts

parallel to each other, give a remarkably smooth and theoretically correct action, which is completely independent of the shape, however crude, of the teeth, as long as it is the same throughout.

Spiral spur gears are often used as skew gears. They run comparatively well in this way; but as there can be only point contact, they wear out very fast and lose considerable power through friction.

Great as are the difficulties in producing good spur gears, they are still greater in the case of bevel gears.

In bevel gears the lines of the teeth converge to a point at the apex of the pitch cone, and therefore the teeth cannot be cut correctly with a rotary cutter or any other formed tool. Yet for a long time these were the only ways of cutting them, and on this account designers of machinery avoided, and still avoid as much as possible, the use of bevel gears.

The correct way of cutting bevel gears is to plane them in such a manner that the stroke of the finishing point of the tool is always in line with the apex, while either the gear blank or the tool is fed in a path that corresponds to the desired shape of the teeth. This feeding movement being angular can only be realized in a polar planer. Inventions to this end have been made by engineers in Europe and in this country.

During the time that I have given attention to this subject I have not been able to investigate these machines, but from what I have ascertained I feel safe in saying that nearly all of them can produce bevel gears superior to those cut in the old way. Only one, however, has been successful in producing them in quality equal to that of the best spur gear now obtainable in practice.

This machine, which planes bevel gears theoretically correct, was invented by Hugo Bilgram, of this city, about eleven years ago. It embodies the process of moulding by a crown wheel or polar rack, the teeth of which are generated by a planing tool with a straight cutting edge, which is set at an angle of 15° or 20°, according to the angularity of the involute required. The work of this machine does not depend on templets of any kind. The shape is generated anew for every tooth by a movement which is

an exact imitation of a plane rolling off a cone. Bevel gears cut by this process are perfectly interchangeable.

Now, what has been said of spiral *spur* gears is also true of spiral *bevel* gears, and however near to perfection the common bevel gear may be when cut on this machine, it can still be slightly improved by cutting its teeth spiral, or of some form of this order. For this operation the same machine is nearly equally well fitted, though this was not the object in view at the time of its construction, and a few slight changes are necessary to increase its range of adjustability.

In the true spiral bevel gear the curvilinear elements of the teeth converge toward the apex of the pitch cone as in the common form. In the spiral bevel gear cut on Mr. Bilgram's machine, however, the elements of the teeth are all tangent to a circle. It is therefore more correctly termed *spiraloidal.* But however it may deviate from the true spiral bevel gear, it has exactly the same virtues, and as very few machinists have heretofore attempted to make gears of this kind, the few specimens here on the table are of especial interest. When tested by hand they will be found to run as smoothly as plain cones.

To derive the full benefit from correctly cut bevel gears it is necessary that they should be mounted with the utmost care. As no two cones can roll on each other continuously without slipping, unless their apices coincide, so no pains should be spared in the mounting of bevel gears to make them satisfy the same condition.

If a bevel wheel is placed in such a position that part of its face is horizontal, its mate, when tried into it by hand, will soon slide into a position where it is in deepest mesh, and which is at the same time the position of smoothest running and of the coincidence of the apices. In the case of theoretically correct bevel gears it is very definitely marked, and though it is easily found in trying them together by hand, much more patience is required to get the gears in that position to each other in the actual mounting. To facilitate this, they are always cut so that at least the outside ends of the teeth of a pair of gears are at the same distance from their apices. Thus, after the shafts are properly located, the gears can be readily brought into a position which is

nearly right by adjusting them until the teeth of both are flush with each other on the outside. But if the best possible result is to be obtained the point of smoothest running must be arrived at much more closely than this by adjusting the gears slightly to and fro, and giving them trials in the various positions. I have repeatedly observed in Mr. Bilgram's establishment that miter gears, about eighteen inches in diameter, when out of adjustment only one thickness of paper, showed a remarkable difference in the noise of their running.

Bevel gears to be well mounted should be encased, whenever possible, to protect them against grit and to deaden whatever noise might otherwise be noticeable. As close as possible to each of them should be the shaft bearings firmly connected with each other, or, better, consisting of a single piece strong enough to keep the gears rigidly in mesh and alignment. Many gears that are a source of annoyance are not only badly cut, but also badly mounted. Were it possible to make bevel gears mathematically exact, their advantage could not be realized if in erecting them the shaft bearings were fastened independently on woodwork, or in any other way that would allow them to change their relative positions.

In bevel gears that are not theoretically correct the point of smoothest running is not so definitely marked. They may be considerably out of adjustment either way without running noticeably worse, for the simple reason that they do not run correctly in any position.

Though bevel gears of the highest quality will give very bad results when carelessly mounted, yet it is entirely within the limits of practicability to get them to perform their duty with comparative noiselessness and absence of backlash, which in the case of poorly cut gears can be brought about by no amount of adjusting.

The distance from the teeth to the apex in any pair of bevel gears intended to work together must be the same, as otherwise the teeth cannot engage. Therefore, if two shafts at a right angle are connected by bevel gears, and the ratio is to be altered by merely using another pinion of a smaller diameter, that pinion necessarily must be more acute, and in order to bring it in mesh with the wheel the shafts have to be set at an angle correspondingly less than 90°. For a similar reason they have to be

set at an angle of more than 90°, if the ratio is to be altered by using a larger pinion. But if a change in the shaft angle is not admissible, then a new wheel, as well as a new pinion, is required. This theory is so well founded and generally accepted that any departure from these rules is considered to be impossible.

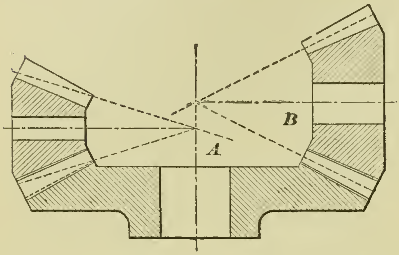
During the time that Mr. Bilgram made it a part of his regular business to cut bevel gears, there was an occasional demand for bevel pinions of different diameters to run at right angles with the same wheel. From a certain experience he conceived the idea that gears of this character were *not* altogether an impossibility. The success of his endeavors to produce them is demonstrated here in this model in which pinions of two inches, three inches, and four inches in diameter gear at right angles with one six-inch wheel. The three-inch pinion is of the regular kind. The smallest and the largest are the irregular or abnormal ones, with teeth of a very peculiar shape. They are, however, of the involute form, and, in fact, this is the only tooth curve which will admit of such a combination.

In the case of cycloidal, or any other form of spur gearing, it is necessary that the gears be mounted, not only parallel to each other, but also at the correct distance apart. In the same way, it is not enough in bevel gearing that the apices coincide; in addition, the shaft angle must be correct, as no proper tooth action can take place unless the pitch surfaces are in rolling contact.

In gears with involute teeth, however, the distance between centres or the shaft angle may be changed within certain well-defined limits, without interfering in the least with correct tooth action. They will simply run like gears with an involute of different angularity, and pitch surfaces of different diameters. This adjustability, which is confined to the involute, and is one of the features that make it preferable to any other tooth curve, has been taken advantage of in the construction of these abnormal pinions.

If to a bevel wheel a second pitch cone of a greater angle is so assigned that it intersects the regular pitch cone about in the middle of the face, the addendum will be larger at the inner end of the teeth, and smaller at the outer end, than before, while with the dedendum this will be reversed. Then, a pinion, smaller in

diameter than the normal one, and with a pitch cone of less angularity, can be easily conceived, the addendum and dedendum of whose teeth correspond to those of the wheel with the secondary pitch cone, as shown in the adjoining cut. The teeth, to be conjugate to those of the wheel, must differ at their ends, not only in size, but also in shape. At every section the involute must be of a different angle, which gives the tooth a rather narrow base at the inner end and a very broad one at the outer, while the sides of the teeth show a peculiar twist. Abnormal pinions, larger than the normal, can be constructed in a similar manner.



Bevel pinions of this kind are certainly very difficult to produce. On Mr. Bilgram's machine, however, they can be cut with no more trouble than the spiral bevel gears. Their strength and efficiency is about the same as that of ordinary gears.

I have said that the teeth of these gears were of the involute form. This needs a qualification. The teeth of any external gear of the true involute system have convex sides, and those of internal ones have concave sides. And as the pitch surface of the crown wheel or the circular rack is the boundary between the external and the internal gear, its teeth must have double curved sides, the faces being concave and the flanks convex. This curvature, however, is very small, and can be seen only when the teeth are of a very coarse pitch.

In the involute rack for spur gearing, the sides of the teeth are straight surfaces. Mr. Bilgram's system of bevel gearing is based on a circular rack, the sides of whose teeth are also perfectly straight surfaces. If a normal cross-section is taken of any bevel tooth of this system, we have the true involute tooth for spur gearing. But, as the real nature of a bevel gear tooth can only be determined by means of a spherical section, it necessarily must be of a different order, and has been named by George B. Grant, the *octoid*.

Although the octoid is a distinctly different tooth curve, from a theoretical standpoint, it is so near to the true involute that the

mechanical errors would be greater than the theoretical difference; therefore, in practice it can be safely accepted as the involute.

Mr. Bilgram will be pleased to show, any time while it is in operation, the machine on which these peculiar bevel gears can be planed.

Mr. H. W. Spangler.—As I understand the description of the method of making these wheels, part of the principal gear is cut to one pitch cone, and part to another. If now one wheel gears with this principal gear or driver, I can understand that it will have line contact over part, at least, of an element running the whole length of the tooth. A second wheel could be made to be driven by another portion of the driver, and having line contact through a portion of the length of the tooth; but a third driven wheel, different from either of the other two, could only have point contact, unless the driver is made up of three pitch cones. That is, the driver and first two gears are practically gears of smaller face than is apparent, and only the third one is abnormal, properly speaking, and in this abnormal wheel is it not a fact that the contact can only be point contact?

Mr. Max Uhlmann:—It is true that the abnormal bevel pinions shown in the model have *theoretically* only point contact.

On the principle described in the paper, different-sized pinions can be made, however, to gear as perfectly with a given wheel as the normal does. But the peculiar form of the teeth is very difficult to produce.

When the teeth are formed by the process mentioned in the paper, the abnormal pinions have line contact with the crown wheel, and also with each other in such cases in which the abnormality of one neutralizes that of the other. Although for other wheels they are only approximately correct, they have sufficient contact with them to be for all practical purposes satisfactory.

When it is considered that in practice line contact is rarely obtained except after the gears are run in, and that for this reason the load is sometimes carried by the weak end of the tooth, the trifling departure from the theoretical line contact is rather favorable, as the load is more likely to be carried by the center of the tooth. Moreover, the approximation is so close to perfection that line contact exists as a result of the elasticity of the metal even before any wear has taken place.

NOTES AND COMMUNICATIONS.

BRIDGE OVER THE RIVER PRUTH, AT JAREMCZE, IN GALICIA.

At the meeting of November 4, 1893, Mr. John C. Trautwine, Jr., sketched upon the blackboard and briefly described the stone bridge recently constructed by the General Direction of the Austrian State Railways over the River Pruth, at Jaremcze, in Galicia. The data were taken from a description by Chief-Inspector Ludwig Huss, in the *Zeitschrift des Oesterreichischen Ingenieur- und Architekten-Vereins,* October 20, 1893.

This bridge, the largest of four thrown across the Pruth by the General Direction, has a span of 65 meters (213 feet), which is believed to be greater than that of any other stone railway bridge in the world, although it is exceeded by the 220-foot span of the Cabin John Aqueduct Bridge in Washington, built in 1859. The rise, as nearly as it can be calculated from the small sketch accompanying Inspector Huss' paper, is about 18 meters (59 feet), which makes the radius about 126 feet.

The Stanislau-Woronienka line follows for 29 miles the deep, narrow, and very rocky valley of the Pruth, on the northeastern slope of the Carpathian Mountains. The rocky and wooded banks of the stream furnish excellent stone for the arches and walls, and timber for the centers, and afford exceptionally good footing for the arches.

The State railway authorities had signified their desire that stone arches should, as far as possible, be employed rather than iron trusses upon the roads in their charge, and the Pruth Valley afforded an excellent opportunity for carrying out these wishes.

The four bridges referred to are similar in general design, consisting of one large segmental arch over the stream, carrying small spandrel arches for the support of the roadway, while the approaches are carried upon semi-circular arches of about 40 feet span, resting upon masonry piers. They are all built for single track only, and are but 4.5 meters (14.7 feet) wide.

Cut stone was employed in those arches which exceeded 40 meters (131.2 feet) in span, rough coursed work for spans from 15 to 40 meters (49.2 to 131.2 feet), and a rubble of flat stones for smaller arches.

To avoid an excess of unequal loading upon the centers during the construction of the larger arches, the innermost ring was first built entire, and the mortar was allowed some two or three weeks to harden before the second ring was begun. The construction of the latter was then commenced at several different points, so that the ring was closed simultaneously at not less than three points.

Inspector Huss informs us that the design of these bridges was largely influenced by the results of the investigations of a special committee appointed by the Austrian Society to investigate the strength of arches.

These investigations, he tells us, showed that the theory of the elastic arch is applicable to masonry arches, but we are not informed to what extent or in what manner this announcement governed the design of the bridges in question.

NUTS AND BOLTS.

At the meeting of November 4, 1893, Mr. Wilfred Lewis exhibited a section of a 7-inch steel stay-bolt, from an hydraulic riveter, which had broken in the nut about $2\frac{1}{2}$ inches from the end of the bolt. The static load on the bolt was 450,000 lbs., but, at the time of fracture, it is possible that the actual load may have been 600,000 lbs. or more, on account of the drop in the accumulator. The diameter of the bolt at the root of the thread was $6\frac{1}{2}$ inches, and the area of the broken section about 33 sq. inches. Had the load been uniformly distributed over the broken section, it is probable that the stress per sq. inch would not have exceeded 20,000 lbs., and that fracture would not have occurred; but a glance at the broken part suggests at once the impossibility of attaining an approximately uniform distribution of load in a bolt-end 7 inches in diameter and $2\frac{1}{2}$ inches thick.

Letting $p =$ uniform stress per sq. inch in the body of the bolt.

$f =$ bending stress in bolt-end for the load p.

$r =$ radius of bolt.

$t =$ thickness of end in supporting nut.

Then it can be shown that

$$f = \left(\frac{r}{t}\right)^2 p,$$

and from this it follows that t should never be less than r; but even when this is the case, the deflection of the bolt-end will cause a very unequal distribution of the load across the section, and without going into an elaborate investigation it must be apparent that however thick the nut may be, the distribution of load across the bolt will always diminish toward the center by reason of the deflection of the bolt-end. That a practical limit will soon be reached beyond which it will not pay to increase the thickness of the nut, is also evident, and on this point it is interesting to refer to the experiments made by the Edgemoor Bridge Works, a report of which has been kindly furnished by the President, Mr. Henry G. Morse. In these experiments a number of bolts were tested with nuts of standard thickness, and, in another set of bolts of the same material, a projecting end was turned down to receive a nut designed to give an additional support to the center of the bolt. In every case an increase in strength amounting to about 3 per cent. was noted, but this was not considered of sufficient importance to warrant the increase in cost. From these experiments it may be assumed that the standard nut of one diameter in thickness develops about 97 per cent. of the strength of the bolt. It is no doubt true that a nut of half this thickness has sufficient shearing strength in the thread, and that such a nut might develop the full strength of the bolt if screwed down far enough from the end, but it should not be assumed from this that nuts of half the standard thickness will answer equally well for general use. If such nuts are placed at the ends of bolts, the bolts will be torn off in detail under much less tension than that required for the common standard.

ETCHING SOLUTIONS.

Contributed by Edward K. Landis, at Meeting of December 16, 1893.—I should like to make the following remarks on Mr. Vauclain's paper, read at last meeting:

Prof. Martens uses solution for etching of 1 part nitric acid, 50 parts ether, and 50 alcohol; also a mixture of muriatic acid and ether, but does not give strength of the latter. He finds that these two solutions give different results.

Dr. Sorby, of England, uses 1 volume 36° Beaumé nitric acid, and 4 of water, with time of etching from a few seconds to one minute.

Garrison, F. L., uses 1 part nitric acid to 1000 parts water for steel rails.

Mr. Bayles uses 1 part nitric acid to 300 of water.

None of these solutions are as strong as that used by Mr. Vauclain, and the time required for etching varied from less than a minute to periods of four days or longer. I think that the use of much more dilute acids for longer periods of time will give very valuable information, especially if accompanied by the use of a microscope, and hope Mr. Vauclain will adopt these suggestions and photograph his results.

MECHANIC ARTS AT THE WORLD'S COLUMBIAN EXPOSITION.

Contributed by Arthur Falkenau at Meeting of December 16, 1893.—The opinion among engineers that the Mechanic Arts Exhibit at the World's Fair was disappointing, seems to be almost unanimous. I believe that this is not so much due to the lack of effort on the part of the exhibitors, or the administration, as to the peculiar condition which the mechanic arts have assumed. Formerly, the advance was so rapid and so broad, that each succeeding exhibition prominently brought to the attention of the engineering world some new application of power, or some entirely new type of mechanism. Thus, there was a time when water tube-boilers, the air-compressor, the direct-acting steam-pump, refrigerating machines, startled the engineer by their novelty. The different fields for the application of power have been so thoroughly exploited, that novel forms are few, and advance is confined more to minor details. In the field of steam engineering, the World's Fair emphasized the fact that the stationary compound-engine has come to stay ; but, as to general types, the detail forms have been so frequently put in a dice-box and shaken out, that all combinations and permutations have become quite familiar even to the general public. The De La Valle steam turbine, which has been described in many of the technical journals, is a marked exception to this rule. To find points of interest, it became necessary to look carefully into details, obtain drawings, and receive information from exhibitors. Through the kindness of Messrs. Warner & Swasey, I am enabled to give you some information as to the general construction of the 40-inch Yerkes telescope. Mr. A. C. Rand, of the Rand Drill Company, has kindly furnished me with drawings, which will enable me to explain some details which are new and will be appreciated by all who have anything to do with air-compressors.

The Yerkes Telescope which, I believe, is the largest instrument of its kind in this country, was erected for exhibition in the north end of the Manufactures Building. I have made a crude sketch, to show the general arrangement of parts, and have given the dimensions and weights of moving parts, which are involved in the purely engineering problems presented. I quote the following from Mr. Warner's paper, read at the Congress of Astronomy and Astro-Physics at Chicago:

In designing a large telescope, the first element, to which the engineer naturally gives his attention, is the tube ; for, while its office is a very simple one, being merely

to hold the objective and the eye-piece in their proper relation to each other, and to enable the astronomer to direct the optical axis to the star, it is an extremely important factor. The two most essential points in the tube are lightness and rigidity, the former for ease of motion, and the latter to reduce flexure to a minimum. The material best calculated to give these two qualities seems, at the present time, to be sheet steel. Some material, having aluminum as a base, has been sought for, but thus far none has been found, giving the requisite rigidity. The form of the tube has much to do with its rigidity, a slight increase in diameter at the center serving to stiffen it to a great degree, and cause thinner material to suffice. No form of internal bracing seems so effective as the same amount of material used in the shell itself. In the tubes of the three large telescopes named, there is, therefore, no bracing whatever, all the strains, both in tension and compression, being taken by the sheet steel forming the tube.

The tube for the 40-inch Yerkes telescope is 42 inches in diameter at the objective end, 52 inches at the center, and 38 inches at the eye end. The sheet steel forming the tube varies from $\frac{7}{32}$ inches in thickness at the center to $\frac{1}{8}$ inch at the ends. The total weight of the tube is six tons.

The declination axis carrying the tube is of forged steel, 12 inches in diameter and 12 feet long, its weight being $1\frac{1}{2}$ tons. This runs in segmental babbitt bearings in the declination sleeve, which weighs 4 tons. The polar axis carrying the whole system is of hard, forged steel, 15 inches in diameter at the upper bearing, and 12 inches at the lower bearing, and weighs $3\frac{1}{2}$ tons.

Just above its upper bearing, it carries the main driving gear, weighing 1 ton, and having 360 teeth, by which the movement of the driving clock is communicated to the polar axis.

The great weight of the bearings of these axes is almost wholly relieved and the resistance changed from sliding to rolling friction by means of three bracelets or live rings of steel rolls. One of these encircles the declination axis near the tube, and one is placed above each bearing on the polar axis. These anti-friction live rings run in steel yokes, and are pressed against the axes by means of adjustable spring levers.

The live ring of rolls, which is on the declination axis near the tube, is the center of gravity of the system, comprising the tube and the declination axis with their attachments, this one series of rolls serving to take the weight off both bearings of the declination axis, and so nearly eliminating friction that less than one pound of direct pressure on the tube is required for each ton of weight moved. This live ring is composed of sixteen rolls, 5 inches long, and 3 inches in diameter, and carries a total weight of 8 tons.

The live ring at the upper end of the polar axis is composed of sixteen rolls, 6 inches long, and 4 inches in diameter. This sustains a weight of nearly 20 tons. The end thrust of all this great weight, due to the angle at which the axis is placed, is taken on a double series of forty 1-inch hardened steel balls.

The methods of balancing the movable parts of the Yerkes telescope have been a special study, with results which seem all that can be desired.

The heaviest accessory to be used with the telescope is the solar spectroscope. With this in position, the tube is accurately balanced. Weights are then placed on the extension of the declination sleeve, until the whole system is in balance. When the solar spectroscope is to be removed, sufficient supplementary weights are placed at the side of the eye-end of the tube, so the balance is not disturbed.

The equatorial head and its bearings supporting the polar axis and the entire movable part of the telescope is cast in one piece, its base conforming to the rectangular shape of the column.

The column is 11 feet × 5 feet at the base, tapering to 10 feet × 5 feet at the head. It is cast in five sections, having internal flanges for securely bolting it together. In the upper section is placed the driving clock. A spiral staircase, at the south side of the column, gives easy access to the driving clock, and also to the balcony surrounding the head.

The driving clock is governed by a double conical pendulum, mounted isochronously, and making sixty revolutions per minute.

A driving weight, considerably in excess of the amount required to drive the telescope, is used with this clock, the surplus of power being taken by a friction ring placed just above the pendulum. The arms of the pendulum are so arranged that in operation they always take their natural and theoretical positions, not being swerved therefrom by the action of the power on the friction ring above mentioned. When the clock is unclamped from the polar axis, all the power required to move the telescope is instantly transferred to the friction ring, and the pendulum maintains its theoretical position and normal rate. An electric motor is provided for automatically winding the clock.

All clamps and slow motions, both in declination and right ascension, are operated by handles at the eye-end within easy reach of the observer, while the assistant on the balcony can also set the telescope in any position and read the circles. In addition, electric motors are provided for operating all quick and slow motions and clamps. These various motions and clamps, being operated by the astronomer at the eye-end of the tube either by hand or by means of the electric motors, and also by the assistant on the balcony, are so arranged that any one method of working them is not interfered with by any of the others. Each motion is therefore always ready for action and no conflict is possible.

The Rand Air Compressor, which I wish to speak of, was located on the south side of Machinery Hall, and attracted my attention particularly on account of its smooth running and lightness compared with the machines of ten years ago. Two main points, the particular system of compounding the air cylinders, due to Messrs. Rand & Halsey, and the use of a mechanical valve-gear, have enabled the attainment of this result.

In the old single, direct-acting air compound the energy applied to the steam piston, being more in the early and less in the latter part of the stroke, was distributed in a manner directly inverse to the work done by the air piston, necessitating a heavy fly-wheel and heavy parts generally, as the machine was subject to shocks, and probably many of those present have noticed the lame, one-legged running of such machines when working under heavy loads.

The first step to ameliorate this state of affairs was to build duplex air compressors with cranks at right angles.

The tandem compound, or two-stage compression system, seeking economy in the work of compression, incidentally causes a better distribution of the load. The cross compounding, however, takes still another step in advance in distributing the load. For gas compressors, where very high pressures are required on account of economy and load distribution, the four-stage compression is used. Until recently, the valves in air compressors were so controlled that their action was uncertain. This was

more particularly true of the inlet valves. To secure a greater factor of certainty, as many inlet valves as possible were put in the cylinder heads, which presented the appearance of a veritable pepper-box. The introduction of a mechanical gear which relieves the spring pressure just before the valve opens and applies it just before the valve closes, two large valves suffice now where six smaller ones were formerly used.

The patent under which the Rand Drill Company works was taken out by Edward M. Strange, November 15th, 1887, and applied for December 2d, 1884. Riedler's patent is, as I understand it, practically the same thing, and, I believe, was issued after Strange's application.

The Rand Company has altered the point of action of the spring on the valve as shown. The retarded reciprocating motion due to actuation by a crank is made use of to keep the valve in nearly one position while open, with quick action at opening and closing.

Another interesting arrangement is the combined air and speed governor. With many air compressors an air governor alone is used, usually consisting of a cylinder having a piston connected to a steam throttle valve, the piston being controlled by air pressure on one side and a spring on the other. In starting up such a machine the engineer must control the engine by means of the hand throttle valve until a sufficient air pressure is attained, after which the air governor acts. Such a compressor is not guarded against running away, in case of accident to the air connections. The arrangement combining the air and speed governor here shown is the design of Mr. F. A. Halsey. By this arrangement either governor may act or both together.

In the German exhibit there were a number of machines of interest, one for forging the thread of worms in the loam mould. I do not suppose it could be used in green sand.

A machine for jig-sawing steel or iron plates carried a saw blade attached at its upper end to a reciprocating head, while the lower end had a heavy weight attached to it.

An interesting detail in the C. W. Hunt exhibit was a connecting rod having a split bushing, which is set up by what is an approach to fluid pressure. A cavity behind the bushing is filled with steel balls of various sizes, so they will not interlock. A set-screw enters this cavity, and, by pressing on the balls immediately touching it, the pressure is transmitted through the rest of the balls to the bushing.

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

September to December, 1893, *inclusive.*

September 16, 1893.—Present: President John Birkinbine, Vice-President James Christie, Directors H. W. Spangler, John L. Gill, Jr., Henry J. Hartley and the Secretary.

The Treasurer's Report showed:

Balance on hand June 1st	$167 97	
Amount received during June, July and August . .	416 48	
		$584 45
Amount expended during June, July and August . . .		567 84
Balance on hand September 1, 1893		$16 61

The Secretary reported that special registered letters had been sent to all delinquent members, and that responses had resulted in an income of $55.00.

The President announced that he had invited the Reception Committee for the visit of the French Engineers to attend this meeting, and they were then introduced. Mr. John C. Trautwine, Jr., Chairman, read the programme prepared for the visiting members of La Société des Ingénieurs Civils de France, and, upon motion, the Board gave the Committee permission to extend to the visitors the freedom of the Club House during their stay in this city. The Committee desired that the members of the Board should suggest the names of suitable persons to be invited to the Reception to be tendered the visitors on the evening of the 26th of September.

The Finance Committee reported that the Club's available assets amounted to about $900.00, and that the liabilities October 1st would reach $1,500.00.

October 7, 1893.—Present: President John Birkinbine, Vice-President James Christie, Directors H. W. Spangler, John L. Gill, Jr., W. B. Riegner, Henry J. Hartley, and the Secretary.

The Secretary read the report of the Committee on Visitors regarding the recent visit of members of La Société des Ingénieurs Civils de France to this city, and upon motion it was ordered read at the Club Meeting of the same date.

There was a general discussion on the bad financial condition of the Club at present. Various means of possible improvement were suggested, and it was finally decided to present the matter to the Club at its evening meeting, with the suggestion that to meet the present imperative indebtedness, members be asked to loan to the Club any amount that they might care to invest, for the Club's two-year notes, without interest.

October 10, 1893.—Present: President John Birkinbine, Vice-President James Christie, Directors Strickland L. Kneass, H. W. Spangler, John L. Gill, Jr., Henry J. Hartley, W. B. Riegner, Wilfred Lewis, and the Secretary.

It was ordered that the meeting of the Club on October 21st be a Business Meeting

for the election of members, the consideration of a proposed amendment to the By-Laws to increase the dues of Resident Members, and the adoption of a plan to advance the social feature of our Club life.

The President stated that at the Regular Meeting of October 7th, twenty members had loaned various sums amounting to $925.00, and seven members had donated $57.00, that other amounts were expected from members not then present, which would bring the total up to $1,500.00 and enable the Club to wipe out its present indebtedness. The loans were to be secured by two-year notes issued by the Club, bearing no interest, and the Chairman of the Finance Committee was instructed to prepare these notes for the signature of the President and the Treasurer.

October 21, 1893.—Present: President John Birkinbine, Vice-President James Christie, Directors Strickland L. Kneass, H. W. Spangler, John L. Gill, Jr., W. B. Riegner and the Secretary.

The Secretary presented letters of thanks from the President of the Austrian Society of Engineers and Architects and from the Chicago representative of the German Engineering Society, for our Club's part in the establishment and maintenance of Engineering Headquarters at Chicago during the Columbian Exposition, and he was directed to present these at the evening meeting of the Club.

Upon motion, the Secretary was instructed to notify the Treasurer that the Finance Committee would obtain and sent to him blank forms for two-year notes to secure those members who had advanced loans to the Club, and that upon receipt of these he should draw up the notes, sign them and send them to the President for his signature.

Upon motion, the Secretary was instructed to present to the Club for approval the plan of the Board to provide a Sinking Fund, equivalent to at least 4 per cent. of the amount of the Loan Fund per month, to be set aside from the current funds and paid over to trustees for the liquidation of the loan.

It was resolved to be the sense of the Board that it was desirable that the dues of Resident Members and Associates should be increased to $15.00 per annum.

November 18, 1893.—Present: President John Birkinbine, Vice-President James Christie, Directors Strickland L. Kneass, H. W. Spangler, John L. Gill, Jr., Henry J. Hartley, W. B. Riegner, Wilfred Lewis, and the Secretary.

The Treasurer's Report showed:

Balance on hand October 1st	$ 34 81	
Amount received during October	1,214 50	
		$1,249 31
Amount expended during October		907 92
Balance on hand November 1, 1893		$341 39

Mr. Gill, for the Finance Committee, gave a list of subscribers to the Loan Fund, to whom notes had been issued, signed by the President and the Treasurer, and endorsed by that Committee.

The Report of the Finance Committee showed the Club's Assets to be $1,241.75, liabilities $1,950.31. Attention was called to the fact that the Liabilities included

the amount of the two-year loan, which was not, on the other hand, included in the Assets, so that the actual condition of the Club was not as bad as the report represented. The Committee was instructed to have the manner of arranging the report changed, so that the actual financial condition would appear.

DECEMBER 16, 1893.—Present: President John Birkinbine, Vice-President F. H. Lewis, Directors Strickland L. Kneass, H. W. Spangler, John L. Gill, Jr., W. B. Riegner, Wilfred Lewis, and the Secretary.

The Treasurer's Report for November showed:

Balance on hand November 1st	$341 39	
Amount received in November	648 68	
		$983 07
Amount expended in November		866 95
Balance on hand December 1, 1893		$116 12

The House Committee reported that the Girard Estate had papered and painted the first floor back and the fourth and fifth floors of the Club House, and had put the plumbing in good order. The Committee was authorized to purchase the necessary gas fixtures for the upper floors.

The Publication Committee reported that the first three numbers of this year's Proceedings had cost approximately $824.42, and that receipts from advertisements, sales of back numbers, etc., amounted to $793.00, making the actual cost to the Club but $31.42.

It was moved and carried that the advisability of presenting authors with reprints of their papers, or with a certain number of copies of the Proceedings in which they appeared, should be referred to the Publication Committee for consideration.

It was moved and carried that the Library Committee be authorized to have the file of bound volumes of the Club Proceedings completed for the Secretary's office.

It was moved and carried that the present salary of the Treasurer be continued for 1894; that the salary of the Secretary's Assistant be made $50.00 per month; that of the Janitress $20.00 per month, and that of the Secretary $200.00 for 1894.

ABSTRACT OF MINUTES OF THE CLUB.

October to December, 1893, *inclusive.*

Business Meeting, October 7, 1893.—President John Birkinbine in the chair; 62 members and visitors present.

The Tellers reported the election of Messrs. Clement Lodge, Henry Delaplaine, Elmer G. Willyoung, and P. H. Johnson to Active Membership, and of Mr. James R. Gwilliam to Associate Membership.

The Committee on Visitors presented their report upon the recent visit of members of La Société des Ingénieurs Civils de France. About forty-seven members of that society reached the city on the afternoon of September 26th, under the escort of the sub-committee, consisting of Messrs. Trautwine, Landis and Loss, who had gone to Washington to meet them, and they concluded their visit and left for New York on the evening of the 28th. There was every reason to believe that their stay in this city was thoroughly enjoyed and that they carried with them many pleasant remembrances.

The report was accompanied by a programme which showed in detail the character of the entertainment provided for the visitors. The Club reception on Tuesday evening was attended by nearly two hundred persons, and was a marked success.

The report acknowledged the obligations of the committee to several members of the Club who assisted in entertaining the visitors, and to several non-members for valuable assistance rendered.

The fund to defray the expenses of this entertainment was raised without drawing upon the treasury of the Club, and without any appeal to the members as such. Nearly one-half of the amount was subscribed by persons who had visited Europe in 1889, and who thereby returned the hospitalities which were extended to American engineers.

The committee also raised a fund of $325 for the purpose of printing and binding the little book prepared by the committee, entitled "List of Objects of Interest to Engineers and Others in and about Philadelphia." These were distributed with the compliments of the Club not only to the party above mentioned, but to many other visiting engineers.

Upon motion the report was accepted, and the thanks of the Club were extended to the committee for their energy in securing subscriptions and arranging and carrying out the programme for the entertainment of the visiting engineers.

The President called the attention of the members present to the fact that the Board of Directors had found, upon assuming charge at the beginning of the year, that there was a deficit in the treasury, the result of several years' falling back, due to delinquencies and the insufficiency of our income to run the Club as it is at present conducted ; and it has not been possible to cancel or materially decrease this.

Prof. H. W. Spangler: The yearly income of the Club from dues is $3,595, which represents about the net income of money we can expect to obtain each year from this source. The initiation fees and dues of new members are not more than enough to cover the loss of members during the year.

The expenses of the Club can be divided something like this:

Rent, gas, etc.	$1,200 00
Salaries	900 00
Printing and loss on Proceedings	350 00
Coal	175 00
Office expenses	250 00
Running the house	150 00
Luncheon	490 00
Making a total of	$3,515 00

It is surely not good business policy to run to within $80 of the possible income, and it is therefore essential that something should be done to prevent the increasing deficit each year.

There seem to me only the following plans:

(1) Reduce our expenses by going into a smaller house. This seems to me very undesirable, and is, I believe, the last step that the Club should take.

(2) Cut off the luncheon, which will give us a sinking-fund of $500 a year, and that will enable us, in time, to wipe out our deficit.

(3) Increase the dues.

But as the matter is so pressing that we must have the money immediately, and as it would be almost impossible for us to make collections up to the end of the year, I would suggest that the following scheme go into effect immediately, viz.:

That a loan of $1,500, in as small amounts as desired by the members, be made for it. The notes of the Club should be given, payable, say in two (2) years, without interest, and to meet these notes a sinking-fund should be established after the first of the year. At the next meeting the proposition for increasing the dues should be again brought before the Club, and, if accepted, go into force at the beginning of the year. This additional income will enable the Club to meet the notes without trouble when they become due or as soon as money accumulates for that purpose.

If, however, the Club does not see fit to increase the dues, then let the luncheon be abolished after the first of the year, and thus enable us to meet two-thirds of our indebtedness at the end of the second year, leaving a comparatively small amount to be carried.

I would suggest that the members present should express their willingness to lend as much as they feel able toward this fund of $1,500.

Two of the officers and two members of the Board offered to start the subscription list with loans of $100 each, and upon a private canvass being taken by a committee of two whom the chair appointed, additional subscriptions to the loan were received, amounting in all to something over $900, and donations amounting to over $50.

The President promised to call a special meeting of the Board at an early day, to take action upon preparing the notes to be issued for the amounts loaned.

Mr. John Birkinbine gave a description of the exhibit of Fried. Krupp, of Essen on the Rhur, Prussia, at the World's Fair. (Published.)

Lieut. William H. Jaques, visitor, gave a description of the exhibit of the Bethlehem Iron Company at the World's Fair, explaining his remarks by lantern illustrations. (Published.)

At the conclusion of his remarks a vote of thanks was extended to Lieut. Jaques for his admirable presentation.

The Secretary exhibited and described a number of slides giving general views of

the grounds and buildings at the World's Fair, which had been kindly loaned for the evening by Mr. C. J. Hexamer.

Business Meeting, October 21, 1893.—President John Birkinbine in the chair; 46 members and visitors present.

The President announced that the Loan Fund started at the last meeting now amounted to $1,125, and that additional subscriptions were expected from members not then present that would bring the total up to $1,500.

The Tellers reported that Messrs. Thomas L. Lüders, Jr., Wm. R. Webster, Richard A. McFadden, Henry Van Buren Osbourn, Amos Warren Barnes, Herbert G. Catrow, Edgar Marburg, Melvin H. Harrington and William Rhodes had been elected to Active Membership, and Mr. Clement D. Rinald to Associate Membership.

Messrs. Edward K. Landis, John C. Trautwine, Jr., Max Livingston, A. Falkenau, H. V. Loss and George T. Gwilliam proposed to amend Article VII., Section 2, of the By-laws, by substituting "$15" for "$10" and inserting the clause "after January 1, 1894," so that the section as amended would read: Article VII. Section 2. —The annual dues of all Resident Members and Associates, after January 1, 1894, shall be $15, and of Non-Resident Members, $5, payable yearly in advance.

It having been thought desirable to hold informal meetings of the members for social intercourse and entertainment, suggestions were invited, and, upon motion, it was ordered that the first one be held on Saturday evening next, 28th instant.

The Secretary read letters of thanks from the President of the Austrian Society of Engineer and Architects, and from the Chicago representative of the German Engineering Society, for our Club's part in the establishment and maintenance of Engineering Headquarters at Chicago during the Columbian Exposition, in the city, and in the Mines and Mining Building at the Fair.

The Board of Directors propose, with the approval of the Club, to provide a sinking fund, equivalent to at least four per cent. of the amount of the loan fund, per month, to be set aside from the current funds, and paid over to the Trustees for the liquidation of the loan. This proposal will be acted upon at the next meeting.

Mr. John C. Trautwine, Jr., described some lantern slides, illustrating the exhibit of the Pennsylvania Railroad at the World's Fair.

Mr. John Birkinbine described the movable sidewalk on the pier at the World's Columbian Exposition, with the assistance of lantern views, showing its general appearance and details of the construction and the method of operation.

The Secretary exhibited a large suite of slides showing the exterior of the Exposition Buildings that were not included in those shown at the last meeting, many of the more important exhibits in the buildings, and scenes in the grounds and Midway Plaisance, with descriptions of the various points of interest connected therewith.

Business Meeting, November 4, 1893.—President John Birkinbine in the chair; 26 members and visitors present.

The Tellers reported the election to Active Membership of Messrs. A. C. Cunningham, Josiah Dow, Edwin F. Bertolett, and Grafton Greenough.

Mr. H. C. Lüders, Chairman, reported for the Committee appointed to solicit subscriptions to the loan, that additional sums had been subscribed amounting to $350, and that additional donations had been received amounting to $30, making the total received to date, $1,432.

There was a lengthy discussion upon the proposal of the Board of Directors, submitted at the meeting of October 21st, to provide a sinking fund equivalent to at least 4 per cent. of the amount of the loan per month, to be set aside from the current funds, and paid over to trustees for the liquidation of the loan.

In answer to a question from Mr. H. C. Lüders, as to whether the amount thus set aside would be used to pay off 4 per cent. of the loans each month, or whether they would all be liquidated at one time, the President stated that the present plan was, when the fund became sufficient for the purpose, to pay 10 or 15 per cent. on all loans, continuing thus until payment was made in full, so that the Club would not only redeem its promise to pay in two years, but would, if possible, do better.

Mr. John Birkinbine (leaving the chair *pro tem.*) said he trusted the recommendation of the Board, or some measure equivalent thereto, would be adopted, whereby immediate preparation would be made for retiring sufficient money to meet at maturity the notes issued by the Club. It should be remembered that the Club did not ask for donations, but for loans to meet a contingency; therefore we are in honor bound to repay that loan within the time named, and for this immediate provision is necessary.

Mr. Arthur Falkenau moved that 20 per cent. of the Club's monthly income from dues be set aside as a sinking fund to pay off the two-year notes, and that three Trustees be appointed by the President to care for this fund, and to distribute it as they might deem advisable. This motion was carried.

The President announced that on the fourth Saturday of the month, November 25th, there would be another meeting for social intercourse and entertainment, which he trusted would be as successful as the last one had been.

Mr. Wilfred Lewis exhibited a section of a 7-inch steel stay-bolt from a hydraulic riveter, which had broken in the nut about 2½ inches from the end of the bolt. The static load on the bolt was 450,000 pounds, and at the time the actual load probably did not exceed 600,000 pounds. It has been found by experiment that when a nut is made to come at the end of a bolt, to obtain uniform stress throughout the bolt, it is not sufficient to make its thickness equal to half the diameter of the bolt, as is generally supposed. The thickness of the nut should be at least equal to the diameter of the bolt.

Mr. Lewis then explained and illustrated a method of calculating the stress in a bolt, showing that it varied with the square of the diameter, and stated that experiments, which he believed verified the equation given, had been made by the Edge Moor Iron Works, but that he was not yet in possession of the figures. (Published.)

At the close of his remarks there was a general discussion on fractures of a similar character, which was participated in by Messrs. Henrik V. Loss, Edward K. Landis, Paul A. N. Winand, and John L. Gill, Jr.

Mr. John C. Trautwine, Jr., with the aid of the blackboard, described the largest one of the four single-track stone bridges which are being thrown across the wild and narrow valley of the River Pruth, in Galicia. This is a segmental arch, varying in thickness from 7 to 10 feet, and having a clear span of 213 feet, with a rise of about 60 feet. It was cheaper, on account of the good material on hand, to make these bridges of stone than to have them built of iron, and the one described above is believed to be the largest stone railroad bridge and the largest stone arch in existence, excepting the Cabin John Aqueduct Bridge, near Washington. In constructing the arch, the lowest or innermost ring, to avoid excessive loading of the centers, was built first

and allowed to remain for two or three weeks before the upper layers were added. These were begun at not less then four points as the springing points and the middle of each haunch simultaneously, and the closing of the ring took place simultaneously at not less than three points. (Published.)

Business Meeting, November 18, 1893.—President John Birkinbine in the chair; 56 members and visitors present.

At the request of the President, Mr. Strickland L. Kneass, Chairman of the Publication Committee, explained for that committee, that the July Proceedings had been delayed through many unavoidable causes, chief of which the loss of Mr. Giron's paper on "Cement," which had necessitated a separation of the two parts and a revision of the discussion by the several members who participated. It is expected, however, that this number will be mailed to the members next week, and the October number will probably appear by the first of next month.

The committee now has under consideration a plan to give to the authors of papers twenty-five copies of the number of the Proceedings in which they are published, at net cost, and larger numbers can be reprinted separately, as at present.

Article VII, Section 2, and the proposed amendment to it as printed in the notice of the meeting, were read by the Secretary.

The Committee appointed to solicit subscriptions to the Club Loan reported that they had secured subscriptions amounting to $590, and donations amounting to $55, which, added to those secured before their appointment, made the total subscriptions $1,590, and the total donations $112, with some other small amounts which can be called for if necessary. Appended to the report were the minutes of the three formal meetings held by the Committee.

Upon motion, the Committee was discharged with the thanks of the Club for their energy and success.

The President announced that, in accordance with the motion made at the last meeting, he had appointed Messrs. James Christie, L. F. Rondinella, and Edward K. Landis trustees of this fund.

Notice has been received of the death, on the 16th inst., at Guayaquil, Ecuador, of Mr. Thomas M. Cleeman, Past President and Active Member of the Club. Upon motion, the Chair was requested to appoint a Committee to prepare a suitable memorial.

A general discussion of the riveting pressures required for bridge and boiler work was opened. (Published.)

The Secretary presented a letter from Mr. Pierre Giron, stating that it was impossible for him to be present at the meeting, and requesting the Secretary to read his paper on the Grinding of Portland Cement, if the meeting desired.

As a very full abstract of the paper was printed in the notice of the meeting, it was read by title only. (Published.)

Mr. F. H. Lewis exhibited a collection of samples of cement briquettes to illustrate the method of preparing and testing them.

The Secretary exhibited for Mr. Edward Samuel a chart showing graphically the results of tests on the deflection of trolley poles made by William Wharton, Jr., & Co., Inc. These showed that the 600-pound pole made with the McCallum joint, of 7-inch pipe, gave better results than the 670-pound pole made with 6-inch pipe by another firm.

Business Meeting, December 2, 1893.—President John Birkinbine in the chair; 59 members and visitors present.

The minutes of Business Meeting, November 18th, were approved as printed.

The Tellers reported that on the proposal to amend Article VII., Section 2, of the Club's By-Laws, so as to read, "The Annual Dues of all Resident Members and Associates, from January 1, 1894, shall be $15, and of Non-resident Members $5, payable yearly in advance," 142 legal votes had been cast, of which 95 were necessary to carry the amendment. 105 votes were in favor of the amendment and 37 were against it. It was therefore carried.

The following is a list of the nominees for 1894, with the names of their proposers and seconders:

A President, a Secretary, and a Treasurer are to be be elected to serve one year, and a Vice-President and three Directors are to be elected to serve two years.

For President.—John C. Trautwine, Jr., proposed by A. Falkenau, seconded by Edward K. Landis. William G. Neilson, proposed by John L. Gill, Jr., seconded by William H. Robinson.

For Vice-President.—J. V. W. Reynders, proposed by James Christie, seconded by Henrik V. Loss. H. C. Lüders, proposed by John L. Gill, Jr., seconded by A. Falkenau. A. Falkenau, proposed by H. W. Spangler, seconded by E. V. d'Invilliers.

For Secretary.—L. F. Rondinella, proposed by Strickland L. Kneass, seconded by H. W. Spangler.

For Treasurer.—George T. Gwilliam, proposed by W. C. Cranmer, seconded by A. E. Harvey, Jr.

For Directors.—Edward K. Landis, proposed by Strickland L. Kneass, seconded by John L. Gill, Jr. Silas G. Comfort, proposed by H. W. Spangler, seconded by John L. Gill, Jr. Henrik V. Loss, proposed by James Christie, seconded by Edward K. Landis. Charles L. Prince, proposed by Wilfred Lewis, seconded by John L. Gill, Jr. H. C. Lüders, proposed by Edward K. Landis, seconded by James Christie. John S. Mucklé, proposed by Wilfred Lewis, seconded by John C. Trautwine, Jr.

In accordance with the By-Laws, the President appointed the following Committee to make any necessary nominations: Mr. S. M. Vauclain, Chairman, and Messrs. John E. Codman, William H. Robinson, H. M. Chance and Wilfred Lewis.

Mr. C. L. Prince called attention to the fact that there seemed to be a feeling among those who had attended the Social Meetings that it would be pleasant to invite the ladies to gatherings of this kind. Upon his motion it was resolved that the advisability of inviting the lady relatives and friends of members to Social Meetings be referred to the Entertainment Committee for consideration and report.

Mr. Max Uhlmann (visitor) read a paper on "Some Novelties in Bevel Gearing," in which he described the method of designing and cutting bevel gears with involute teeth, so that one wheel would be able to gear with several pinions of different diameters and numbers of teeth.

His remarks were illustrated by a handsome collection of cut gears including spur wheels, bevel gears with spiral teeth, normal bevel gears with involute teeth and abnormal pinions. These were cut by a machine designed and built by Mr. Hugo Bilgram. (Published.)

The discussion on the riveting pressures required for bridge and boiler work was continued. (Published.)

At the conclusion of this discussion, Mr. John C. Trautwine, Jr., introduced Mr. H. H. Suplee, who has kindly presented the Club with a copy of his translation of "The Constructor" by Reuleaux.

Mr. Suplee spoke of the interest that had been manifested by the latter at the World's Fair in Mr. Bilgram's exhibit of abnormal bevel gears.

Business Meeting, December 16, 1893.—President John Birkinbine in the chair; 33 members and visitors present.

The Tellers announced that 101 votes had been cast, electing to Active Membership Messrs. James Madison Porter, John T. Rowland, Jr., Isaac Roberts Newkirk, J. Charles Ziegler and Herbert E. Havens, and to Associate Membership Messrs. S. E. Moore, Charles M. Gwilliam and J. Lindsay Little.

Resignations of Active Membership were presented and accepted from Messrs. S. H. Chauvenet, William Burnham, William E. Good, Francis H. Saylor, Fairman Rogers, John A. Wilson, Charles G. Darrach, Joseph Hartshorne, John S. Naylor, C. W. Durham, Morris W. Rudderow, Emile Low, William H. Bixby, Henry B. Seaman and F. M. Smith. The resignation from Associate Membership of Mr. A. J. Rudderow was also presented and accepted.

The President called attention to the fact that while sixteen resignations seemed a great many to be presented at one time, there were always several at the end of the year, and as only three of these were dated after the amendment increasing the dues had been carried, it was therefore not likely that many of them were owing to this change in the expense of Club membership. From after the annual meeting last year there were twenty-one resignations, while for the same period of this year there have been twenty-two.

The President announced that the Board had appointed the following gentlemen to examine and certify to the Treasurer's accounts for 1893: Auditors, Mr. H. C. Lüders, Chairman, with Messrs. Max Livingston and E. V. d'Invilliers; Alternates, Messrs. Henry Leffman and William H. Robinson.

The President also announced the appointment by the Board of the following gentlemen to serve as Tellers to conduct the elections in 1894: Tellers: Mr. George W. Irons, Chairman, with Messrs. R. H. Klauder and R. Boericke; Alternates, Messrs. William Vollmer and John E. Codman.

The Committee on Entertainment, in accordance with the resolution passed at the last meeting, had considered the advisability of having a Ladies' Day at the Club house in the near future, and reported that such a move was not deemed advisable or likely to produce results to warrant the necessary expenditure.

Mr. John Birkinbine exhibited a hemisphere of metallic ore highly polished and with a $\frac{3}{8}$-inch hole drilled slantingly through its upper part, and stated that, while traveling in Mexico, a companion, having promised to get him a meteorite, upon reaching Pueblo had presented him with this specimen. The donor believed it to have been a very old mirror, but the holes seemed to be too small to have served for finger places.

It was extremely hard, being capable of scratching glass, and to get some particles for analysis, it had taken three-quarters of an hour to drill a very shallow hole in it.

How long, then, must it have required to drill a hole $1\frac{3}{4}$ inches long through the material?

Mr. E. K. Landis, who had analyzed these borings, had found that the specimen was an iron pyrites with about 43 per cent. each of sulphur and iron, with the other ingredients still to be analyzed.

Mr. A. Falkenau described some interesting features that he had studied in the Department of Mechanical Engineering at the World's Fair. (Published.)

The main points to which attention was called were the methods of construction in the 40-inch Yerkes Telescope, and details regarding air compressors, exhibited by the Rand Drill Company.

Mr. S. M. Vauclain exhibited a fine suite of specimens alluded to in his discussion on "Riveting Pressures," at the last meeting. These had been planed through the bolts to show how they filled the holes, and then treated to an acid bath, which showed the direction in which the iron had flowed. They proved all that had been said at the last meeting with regard to the proper pressures for different diameters.

The President announced that the present volume of the Club's Proceedings would soon be issued, and that the Publication Committee had now in course of preparation a complete index of the ten volumes which comprise the entire set. It is believed that this will form a valuable adjunct, and make the many useful papers more easy of reference than they have heretofore been.

Proceedings, Engineers' Club of Philadelphia, Vol. XI, No. 2, January—March, 1894.

John C. Trautwine, Jr.

Elected President, January 20, 1894, for the Seventeenth Year of the Club, A. D. 189

PROCEEDINGS

OF THE

ENGINEERS' CLUB OF PHILADELPHIA.

ORGANIZED DECEMBER 17, 1877.

NOTE.—The Club, as a body, is not responsible for the statements and opinions advanced in its publications.

Vol. XI.] JANUARY-MARCH, 1894. [No. 2.

ANNUAL ADDRESS

OF

JOHN BIRKINBINE, Retiring President.

Delivered, January 20, 1894.

GENTLEMEN:—Article II, of the By-laws, provides as one of the duties (?) of the President, the presentation of an Annual Address before the Club, and naturally the first thought is to follow some of my predecessors by offering a general resumé of engineering progress during the past year.

Notwithstanding the severe business depression which for most of the year 1893 affected all industry, great advances are recorded in various branches of our profession, more than sufficient to furnish data for an interesting statement. Then, too, the World's Columbian Exposition, which for several years engrossed so much attention and demanded such engineering skill in its construction, and which for half of the past year drew millions of visitors, suggests many features of engineering progress, which are deserving of notice.

It is, however, my purpose to pass these attractive topics, and invite the members to consider features of more local interest, and I trust of greater immediate service to the Club, than a statement either of the advance made in the profession through-

out the world, or of the lessons taught by the Exposition lately closed.

This action is not taken for want of appreciation of what engineers in our own country and foreign lands have accomplished, nor should it be assumed as a failure to recognize what was taught by the construction and administration of the "White City," with its marvelous exhibits of the best that the world produces. Omitting details, we may consider the American Ferris Wheel as a rival of the French Eiffel Tower, in emphasizing the utilization of structural iron and steel noticeable in the high buildings which shade the streets through which we daily pass. The Siberian, the Trans-andine and the African Railways, follow the bold schemes which made our trans-continental roads successful. The construction of a steam railway to the summit of Pike's Peak in this country is an offset to the crossing of the Simplon Pass in Europe, while the application of 150,000 horse-power from the Niagara River may be considered as a fit companion to the new Manchester Ship Canal. Many additional engineering features might be suggested, but these are merely offered as prominent examples of what is being accomplished.

The membership of the Engineers' Club being composed chiefly of residents of Philadelphia and vicinity, or of engineers who either by home ties, professional or business connections are especially interested in the city of Philadelphia, I feel impelled to present some reasons for the existence of such an organization in a manufacturing city of 1,200,000 inhabitants, and to offer suggestions concerning the mission of our association.

Toward the end of September (1893) the Club had as most welcome guests, a delegation from the French Society of Civil Engineers, and one of the first courtesies offered to the visitors was a birds-eye view of the City from the tower of the Public Buildings. The thought which I shall attempt to emphasize, was suggested while standing on the lofty platform overlooking the panorama representing investments which can only be estimated from the assessment of the real estate, valued for taxation at $800,000,000. The atmospheric conditions were particularly favorable, and evidences of hundreds of active

industries appearing on every side, impressed one with the important part the engineer had borne in the creation, development and improvement of the City, and the numerous local demands upon his skill and knowledge at the present time.

If an investigator should traverse the 129 square miles embraced in the city limits, and peer into the odd corners of the 250,000 edifices which are placed upon this area, thousands of surprises would be disclosed, many of which would be of special interest to engineers.

In his journey he would walk graded streets and roads aggregating in length the distance from Philadelphia to Omaha (1,300 miles), and cross 268 bridges; the paved portion of the streets being sufficient to extend from Philadelphia to Chicago (800 miles). Below the surface of the streets and roads there are gas mains varying from 2 inches to 30 inches in diameter, sufficient, if laid continuously, to reach beyond the Mississippi River (1,100 miles); a length of water mains ranging from 3 to 48 inches in diameter, which could connect New York City and Jacksonville, Florida, (1,070 miles); sewers of from 1 to 20 feet in diameter which, if constructed in one direction, would terminate at Baltimore on the South and at Montreal on the North (550 miles); and a score of miles of electric conduits, pneumatic tubes, etc. During the year 1893, 75 miles of sewers, and an approximately equal length of gas and water pipe were placed in the streets of Philadelphia.

The surfaces of these streets are gridironed by street railway tracks almost sufficient to reach from Philadelphia to Pittsburgh (325 miles), and disfigured by a wilderness of poles carrying thousands of miles of telegraph and telephone wire. Over 20 miles of wire are represented in the single span over the Schuylkill River at Market Street, and the Municipal Government supports over 400 miles of line, which means a length of wire many times as great.

The alignment, grading and paving of the streets, the construction of sewers, street railway and telegraph lines, the laying of water and gas mains and other connections, have all made demands upon the engineer, no less than the plants with which they are connected. The diversity of these plants may be illus-

trated by referring to the 23 steam engines of different types and capacities, varying from 250,000 to 20,000,000 gallons per day, which with the 7 turbine wheels can supply a total of over 200,000,000 gallons of water daily to the 10 reservoirs holding an aggregate of over a billion gallons, placed at elevations of from 94 to 414 feet, with high service tanks over 100 feet higher still; or by the 2,300 gas retorts daily furnishing, in addition to other private works of about one half the capacity, 16,800,000 cubic feet of gas through 23 holders of from 25,000 to 1,800,000 cubic feet capacity, to 145,000 consumers, and 20,000 street lamps. Add to these the plants furnishing thousands of electric lights, supplying power for cable and trolley street railroads, and the engineering problems under the direction or subject to the inspection of the municipality are legion.

If we turn now to the railway interests centered in Philadelphia, figures fully as startling are presented, for here are the executive and adminstrative officers of two great railway systems, and the headquarters of other similar organizations of importance.

The two superb terminal stations, whose train sheds have spans greater than any other permanent buildings in the world, make Philadelphia pre-eminent, in this particular, and are appropriate representatives of the 150 miles of railway laid within the city limits. On these 150 miles of roadway are nearly 100 passenger stations, at which and to which, tickets are sold; and also numerous freight depots, grain elevators, enormous coal docks, merchandise and shipping wharves, with steam-boat transfers, etc., all within the city boundaries. The road-beds cross ten important bridges, numerous viaducts, street bridges, etc., and pass through four tunnels. In fact, the engineering problems connected with the railway construction within Philadelphia represent nearly every phase of such work, and some details have been most difficult of solution. The abolition of grade crossings has taxed and will continue to tax the skill of engineers representing both the City and the railroad companies, until this good work is completed.

The length of track represented by the 150 miles of railway and its sidings, is equivalent to a single track road 674 miles long,

with bridges, tunnels, grades of varying percentages and curves of varying degree, earth and rock cuts, embankments, pile, crib, caisson and stone foundations, etc.

The Pennsylvania Railroad Company has within the city of Philadelphia track mileage equivalent to a single-track railroad from this city to Pittsburgh, and sufficient to spare for sidings equal to one-ninth of the length of this main line.

The Philadelphia and Reading Railroad Company maintains a trackage inside of city limits sufficient for a double-track road between Philadelphia and Pottsville, and in addition a third track extending from the Terminal to and five miles beyond Reading. The Port Richmond Branch of this road alone, including the coal docks, represents 82 miles of track.

Probably more than 100,000 gross tons of rails are in place to-day, within the boundaries of the City, for the use of the steam roads and for street car traffic (omitting private sidings).

The United States Government has assigned to the city of Philadelphia, engineers representing the Army, the Lighthouse Board and the Coast Survey, and under the direction of the first of these, 2,500,000 cubic yards of material have been removed from the Delaware River during the latter half of the past year, two islands having been practically transported to the lower part of the City. This however, represents but a fraction of the total material which the improvements to the harbor now in progress will cause to be moved; for when these are completed, 21,500,000 cubic yards will have been handled, and great additions and improvements made to the river-front docks.

Do we appreciate what 21,500,000 cubic yards mean? This quantity of earth placed along the entire length of Broad Street (9 miles) and of Market Street ($5\frac{1}{2}$ miles), would raise the grade of both streets between house lines 70 feet. The material moved in the past 6 months, would, if placed on Broad Street, elevate its surface 12 feet for its whole length, bringing the street level with the second stories of existing buildings.

Additional data concerning what may be considered either as municipal or practically public works could be offered, such as a total of 6,600 stationary steam boilers in the city used for power, with an aggregate of 276,000 horse-power, carrying steam rang-

ing from 20 to 200 pounds per square inch, an average of probably 90 pounds. The aggregate grate surface of these boilers exceeds two acres. This of course is exclusive of boilers on locomotives, steam vessels, etc.

The receipt, handling and shipping of 7,500,000 tons of coal annually, of which nearly 4,500,000 tons are consumed within the city limits, offers further food for thought. However, enough has been noted to show the magnitude and variety of enterprise which are so familiar that we scarcely appreciate them.

We walk the City's streets, cross its bridges, travel its railways, enter its buildings, work in its industries, but seldom recognize that there is so much which is really impressive.

It would be interesting to follow a similar line of inquiry as to diversified industries and private enterprises, showing the extent to which the engineer is a necessity for their creation, their development and their administration. These are so numerous and the scope so wide that mere mention of a few only of the more prominent can be made.

No city in the world has supplied so many locomotives as Philadelphia, none to-day has greater producing capacity, and the largest manufacturer of these marvels of engineering skill is in our midst. Among the first to enter this line of construction, it has developed in its sixty-two years of existence, from a small works producing one engine of less than five tons in weight, and of limited horse-power, per annum, to an immense plant capable of accommodating 5,500 workmen, whose labor is supplemented by machinery of 5,000 horse-power, completing nearly 1,000 modern locomotives per annum, some of which approximate 100 tons in weight.

Were it possible to collect the 13,500 locomotives which have been built at these shops, they would represent a value of $120,000,000, and if placed end to end on a line of railroad, would cover a stretch of 125 miles, presenting an object lesson of mechanical progress in which all may glory. Who can measure the influence which this great works has had upon engineering, not alone in Philadelphia or Pennsylvania, but throughout the United States, and in fact over the whole world. How many busy hands elsewhere are required to mine each week

1,000 tons of coal and produce 1,500 tons of iron and steel in various forms to supply this one local industry.

The shipbuilding interest is prominent among Philadelphia's industrial laurels; the value of which is too often judged from the liberal amount of money represented by the wage pay rolls, rather than from the higher plane which recognizes the problems solved in designing and constructing the great ships built on the Delaware, or of manufacturing, framing and assembling the various parts.

Philadelphia builds and equips the largest war vessels, and a ride of two hours will take one to works fabricating the most powerful guns, the heaviest armor plate, and the most penetrating shot and shell. All material used in the construction of vessels is made within or close to Philadelphia.

Our greatest ship works furnish employment to 5,400 men (whose earnings last year reached a total of $3,000,000, owing to wages being maintained in spite of business depression), and has built nearly 300 large vessels and half as many marine engines. It had under contract and construction, at one time, war, merchant and passenger vessels aggregating a registered tonnage of 147,000, and machinery aggregating 236,000 horse-power; a record unequaled.

The plant of an oil refining company covers about 150 acres of the City's area, it has steam boilers of 10,000 horse-power, and gives employment to 3,000 men. Crude oil from the oil regions of Pennsylvania and West Virginia is received by two pipe lines hundreds of miles in length, at the rate of 1,000,000 gallons every twenty-four hours. During 1893 about 400 vessels were loaded, carrying away nearly 250,000,000 gallons of oil (upwards of 725,000 tons), and in addition shipments to the surrounding home territory were made, amounting to about 100,000 gallons daily.

As a producer of machine tools, the reputation of Philadelphia is world-wide, and the scope of this manufacture includes the largest gun lathes, the heaviest bending presses, as well as the delicate mechanisms on which are produced dental instruments. Powerful pumping and hoisting engines, heavy rolling-mill work, large and intricate open-hearth steel castings, bridges, roofs, saws,

files, and similar products are the bases of other prominent industries.

Mention of our immense sugar refineries (one of which uses boilers of 16,000 horse-power), demanding in their construction and equipment the highest class of engineering, could be supplemented by reference to large textile industries and other specialties, and the list of objects greatly lengthened.

As an evidence of special work done in Philadelphia, the statue of William Penn, which is to surmount the tower of the $20,000,000 Public Buildings, and the columns of the tower deserve mention here. This statue, 38 feet high, weighing 27 tons, ranks third in size among modern bronze castings, and is the largest cast in America. The columns are the most notable examples of applying copper and aluminum electrolytically to castings weighing five tons and over.

How many members of the Club realize that in Philadelphia there are, with one or two exceptions, examples of all the prominent steps in the advance of stone and metal bridge building, the latest addition being the first bridge constructed entirely of concrete in America, and in this connection the fact must not be overlooked that most of our bridges have been designed and constructed by local engineers, the great bulk of material being obtained from or fabricated in the immediate vicinity of the City.

How many appreciate the extent and variety of engineering constructions or diversified interests which are on all sides of us.

The statements made have been confined to some prominent features of interest to engineers within the corporate limits of the City; but extending the inquiry to adjacent territory, many more are found. The Delaware and Schuylkill Valleys abound in industries, blast furnaces, steel works, rolling mills, foundries of magnitude, machine shops, factories, etc. All these demand the skill and experience of the engineer in designing, constructing and managing or supervising, and most of these are directed or controlled by citizens of Philadelphia.

The question will naturally arise—"Why have these statements been presented?" They are not all new, and in a number of cases exact figures have been purposely discarded for more general

data.* Most of the facts offered in this imperfect resumé have been supplied by members of the Club, others were gleaned from the admirable handbook issued in the name of "The Engineers' Club of Philadelphia," the work of your President-elect. I congratulate you that the modesty which caused him to omit his name from this very creditable compilation did not prevent the Club from recognizing his efforts for its advancement.

The statements which have been presented have been offered for the following reasons:

First, to invite the attention of members to some of the "big things" of Philadelphia. The list is far from complete, and each member can probably suggest additions deserving a place in the record. If such is the result, I shall be gratified, for a realization of what Philadelphia and vicinity now possesses will do much toward securing a proper appreciation of its merits. The Engineers' Club suggests an appropriate medium for making these merits known. Let it be the Engineers' Club of and *for* Philadelphia.

Second, to indicate how many are engaged in pursuits which should bring them into an organization where mutual interchange of ideas and personal acquaintance can be utilized for the advancement of the profession. The roll of members to-day includes the names of men associated in all branches of the large works which have been mentioned.

Third, the summary given exposes a field from which subjects for papers and discussions could be obtained. A practically limitless variety of topics is at our door, replete with interest and value to all who participate in or listen to discussions thereon. Topics can be obtained at home, equaling in importance and interest those sought for afar.

Philadelphia possesses a constituency to sustain an Engineers' Club, but the roll of membership is far from including all who should be associated in it. While two hundred and eighty-four resident and one hundred and sixty-eight non-resident members form a strong organization, the number should be largely increased, and this will probably be the result if the members

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* More exact figures are given in the appendix.

present the claims of the Club properly to their friends, of whom several thousand are possibly eligible under the present Constitution.

The provisions are:

Art. III, Sec. 2.—Civil, Mechanical, Mining and Electrical Engineers, Geologists, Architects and others who are actively engaged in or who have been in responsible charge of engineering work, or who have been connected with the same as teachers, shall be eligible to membership.

Art. III, Sec. 5.—Associate Members shall be persons who are interested in the advancement of Engineering Science, and who will participate in promoting the interests of the Club.

Strength in numbers is not the only desideratum. Interesting meetings will advance the Club more rapidly than any other feature and also increase its membership. In such an organization there is of necessity diversity of interests, and papers of value to each special coterie must originate with those most familiar with the details. A failure to present subjects of a character appreciated by certain specialists does not rest with the Directors, but with those conversant with that particular branch of Engineering.

An experience in other engineering organizations, verified during my official connection with this Club, demonstrates the fact that some contributions which have drawn out the fullest discussion have resulted from the presentation of data or experiences which the writer did not recognize as of special interest, because of his familiarity with them, the same being presented only at the solicitation of the officers, or suggestions of fellow-members.

If an attempt were made to summarize topics for papers and discussions, from the prominent features herein mentioned, the list would be extensive, but hundreds of specialties less pretentious, which have not even been referred to, present equally interesting suggestions. A particular design, construction, method or process, familiar to a member, may be a revelation to others; that which is a subject of daily routine to one may be a most interesting and instructive novelty to many.

Some who have the most to tell are the least willing to enter-

tain; not from an ungenerous feeling, but more often from a modesty which leads one to discount his ability, forgetful of the fact that the Club is organized for mutual help and not for unfriendly criticism.

There are also many subjects upon which an engineer must be silent in deference to the wishes or in justice to the interests of those he represents; but making ample allowance for these, the opportunities presented are far from restricted.

There have been and there will continue differences as to the ethics of engineering, in the matter of advertising, but there is probably no better way for an engineer to make himself known than by contributing papers upon or participating in the discussion of technical subjects. An engineer's capital is his reputation. A more extended knowledge of his achievements and a greater confidence in his conclusions are additions to his working capital. Participation in the Club's Proceedings is, therefore, advisable from a selfish standpoint, but judged from that of co-operation it is still more commendable.

As the membership of the Club includes men renowned in various specialties of Civil, Mechanical, Mining, Electrical or Sanitary Engineering, Geologists, Chemists, etc., an audience competent to discuss any paper relating to Engineering or kindred sciences can be had if the subject-matter is made known in advance.

The Social feature of the Club is important and deserves to be more fully developed; we need to know each other better, to be more helpful to one another. As at present organized, we form a technical society, and as such, the papers presented and discussions had thereon will largely determine the attendance at meetings, giving opportunity for extending personal acquaintance and mutual assistance; while the prompt publication of these papers and discussions in the Proceedings, is all the return which can be offered non-resident members; they should, therefore, be as varied and as valuable as can be secured, and in this all can aid. Non-residents have limited opportunities to make use of the privileges which the Club House offers.

Let us remember that the duty of securing topics for meetings, the preparation and publication of the Proceedings and

the conduct of all details of Club management are voluntarily assumed by members whom you select as officers. Your aid lessens the labor and encourages them in the services which are rendered without compensation other than your approbation.

In retiring from the office of President, to which your consideration elevated me, I would be forgetful did I fail to express the pleasure which has marked my official connection with the Club during the past year. My greatest source of regret is that business called me away for a portion of the year when I could posssibly have been of the most service.

Part of the equipment of the assembly room of the Club House consists of a gavel and a book upon "Rules of Order." It is a pleasure to be able to say that the former has merely been used for the purpose of attracting attention, and has not been necessary in any case to secure proper order. The business of the Club has been transacted with so much good feeling that the Rules of Order have lain by unused.

Expressing to you my thanks for the consideration which has made the year pass so pleasantly, I would ask that you continue to support the one whom you have chosen as my successor as faithfully as you have him who now retires.

APPENDIX.

The following data obtained from the parties named, were used in the preparation of the Annual Address, and are given so that those especially interested may have more exact figures than appear in the text.

Mr. George S. Webster, Chief Engineer and Surveyor, member of the Engineers' Club, supplied the following:

Area of city of Philadelphia, 129 square miles.

Number of miles of streets and roads, 1,297.69.

Number of miles of streets and roads paved, 852.14, less 31 miles of turnpike, equals 821.14 miles.

115.46 miles of main sewers, varying in size from 12 inches to 20 feet in diameter, and 507.21 miles of branch sewers.

Approximately 20 miles of electric conduits, pneumatic tubes, etc.

The City has 242 bridges, and in addition 70 bridges kept in repair by railroads, not including railroad bridges proper.

There are 302.2 miles of street railways.

The City service telegraph, telephone and electric light lines aggregate 400 miles.

Broad Street is 113 feet between house lines, and opened for 9 miles.

Market Street is 100 feet wide, and is opened for $5\frac{1}{2}$ miles.

Mr. John L. Ogden, Chief Engineer of the Water Department, gives the length of water mains from 8 to 48 inches in diameter as 1,081.5 miles, of which over 50 miles were laid in the year 1893.

Twenty-three steam engines of different types, varying from 250,000 to 20,000,000 gallons capacity per day, and seven turbine wheels, supply a total exceeding 230,040,000 gallons per day to ten reservoirs, holding in the aggregate 1,017,288,814 gallons, placed at elevations of from 94 to 414 feet.

The following table shows the type and capacity of the various pumps and turbines of the Philadelphia Water Department.

TABLE I.

	Pumping Station.	Designated No. of Engine or Turbine.	Type of Engine.	Designed Capacity in Million Gallons per day.	Total.
Spring Garden.	Old Station	4	Worthington Duplex	20,000,000	
	"	5	Compound Rotary	20,000,000	
	"	6	Simpson Compound Rotary	10,000,000	
	"	7	Marine Compound Rotary	20,000,000	
	"	8	Worthington Duplex	10,000,000	
	"	11	Gaskill	20,000,000	
	New Station	9	Worthington Duplex	15,000,000	
	"	10	" "	15,000,000	
					130,000,000
Belmont		1	Worthington Duplex	5,000,000	
"		2	" "	5,000,000	
"		3	" "	8,000,000	
					18,000,000

TABLE I.—CONTINUED.

Roxborough..............	1	Vertical Compound..........	12,000,000	
"	2	Worthington Duplex.........	5,000,000	
"	3	" "	7,500,000	24,500,000
Roxborough Auxiliary	2	Knowles' Pump..............	250,000	
" "	3	" "	250,000	500,000
Mt. Airy	1	Davidson Pump	1,000,000	
"	2	" "	1,000,000	
"	3	Knowles' "	1,000,000	3,000,000
Chestnut Hill	1	Knowles' Pump..............	250,000	
"	2	Worthington Duplex.........	500,000	750,000
Frankford..................	1	Marine Compound Rotary..	10,000,000	
"	2	Corliss Compound Rotary...	10,000,000	20,000,000
FAIRMOUNT. New House...........	1	Turbine Wheels..............	2,000,000	
"	3	" "	5,330,000	
"	4	" "	5,330,000	
"	5	" "	5,330,000	
Old House	7	" "	5,100,000	
"	8	" "	5,100,000	
"	9	" "	5,100,000	33,290,000
Total..				230,040,000

Additions provided for:

Spring Garden Station,	2 engines,	30,000,000	gallons each.		
Frankford	" 1	"	15,000,000	"	"
Queen Lane	" 4	"	20,000,000	"	"
Total..............	7 engines,	155,000,000	gallons.		

The following is a tabular statement of the location, date of completion, elevation and capacity of the City's reservoirs:

TABLE II.

Name of Reservoir.	Location.	Date of completion.	Height above City datum.	Capacity in Gallons.
Fairmount. Reservoir, No. 1	East Fairmount Park	1815	94	26,350,800
" " 2		1821		
" " 3		1827		
" " 4, Section 1		1835		
" " 4, " 2		1836		
" " 4, " 3		1836		
Lehigh. Section 1	Sixth Street and Lehigh Avenue	1852 and 1871	114	26,394,000
" 2				
" 3				
Spring Garden	Twenty-sixth and Master Streets	1844	120	12,000,000
Corinthian	Corinthian Avenue and Poplar Street	1852	120	37,341,400
East Park. Section 1	East Fairmount Park	1887	133	62,737,632
" 2		1888		306,400,622
" 3		1889		304,736,360
Frankford	Oxford Turnpike and Comly Street	1877	167	36,046,000
Belmont	West Fairmount Park	1870	212	39,758,000
Mount Airy	Allen's Lane and Mower Street, Germantown	1851	363	4,546,000
Roxborough	Ridge and Shawmont Avenues	1866	366	12,838,000
Manatawna tanks—2	Manatawna and Ridge Avenues	1878	442	100,000
Chestnut Hill tank	Hartwell Avenue and Chestnut Hill Railroad, Chestnut Hill	1860	481	40,000
New Roxborough	Port Royal Avenue and Ann Street	1893	414	148,000,000
Total				1,017,288,814
Under Construction:				
Queen Lane Reservoir				386,000,000

During the year 1893, 265,911 feet of pipe were laid equal to 50 miles, 1,911 feet; 96,066 feet of pipe were re-laid (which adds nothing to the feet in ground). 1,000 fire hydrants were placed in position (all of the new style), while 323 new style and 10 old style hydrants were substituted for defective ones. There are now 8,884 fire hydrants in use, and a total of 11,892 water attachments.

Mr. H. K. Nichols, Chief Engineer of the Philadelphia and Reading Railroad Company, gives the number of miles of track operated by them as follows:

	Miles of road.	Total miles of track.
Main line, City line and terminal	13.24	125.08
Philadelphia, Germantown and Norristown, and Chestnut Hill	18.07	59.78
North Penn and New York Division	11.20	47.42
Philadelphia and Chester Branch	5.30	9.44
Miscellaneous branches	3.34	7.50
Total	51.25	248.77

Of this total, 38.40 miles are double track, 12.85 single track, and 159.12 miles of sidings.

Mr. J. Van Smith, Superintendent and General Agent of the Baltimore and Ohio Railroad, states that the B. & O. R. R. has in the city of Philadelphia 14.55 miles of track, equaling 29.1 miles of single track and 13 miles of sidings, making a total of 42.1 miles.

Major C. W. Raymond, Corps of Engineers, U. S. A., states that on December 31, 1893, 3,225,163 cubic yards of material had been taken by dredging from Windmill, Smith and Petty Islands, and adjacent shoals. Of this amount the American Dredging Company, between July 1st and December 31, 1893, had removed 2,419,431 cubic yards of material. During December 491,253 cubic yards were handled.

Mr. John H. Converse, member of the Club, says: The Baldwin Locomotive Works were established in 1831, and on May 1, 1893, had completed the 13,420th locomotive. They employ 5,100 men, consume approximately 1,000 tons of coal, and 1,500 tons of iron per week, and the buildings cover 16 acres. The lightest engine built weighed 5,100 pounds, and the heaviest 195,000 pounds. The boilers have a capacity of 5,000 horse-power (Circular of May 1, 1893).

Mr. Chas. H. Cramp, President of the William Cramp & Sons Ship and Engine Building Co., and member of the Engineers' Club, states that the number of men employed during the week ending January 10, 1894, was 5,377, exclusive of the office force. The amount disbursed in wages, salaries, etc., during the year 1893 was within a fraction of three million dollars.

Mr. Max Livingston, Superintendent of the Refining Department of the Atlantic Refining Company, and member of the Engineers' Club, reported the data for this plant.

Mr. John Overn, Chief of Bureau of Steam Engines and Boilers, and member of the Engineers' Club, states that on December 31, 1893, the number of boilers inspected by the City was 3,302 and 3,290 were examined by insurance companies, a total of 6,592. The average steam pressure was 90 pounds, the approximate grate surface 92,000 square feet, an average per boiler of 14 square feet. The power based upon a consumption of 5 pounds of coal per hour per horse-power, gives a total of 276,000 horse-power.

III.

THE ENGINEERING PROBLEM OF IRRIGATING LARGE AREAS.

Lecture delivered by MAJOR J. W. POWELL, *Director U. S. Geological Survey*, before the Club, *January* 6, 1894.

[Major Powell has found it impossible to prepare the manuscript copy of his lecture, in time for publication in this number.]

IV.

THE MAGNETIC CONCENTRATION OF IRON ORES.

By Edward K. Landis, Active Member of the Club.

Read, February 3, 1894.

This subject, although practised for a considerable time, is commercially a new one. The method consists in passing the previously crushed ore over a machine so arranged that the magnetic particles of the ore are concentrated, or collected together by themselves, while the non-magnetic particles are left behind. These two materials are known respectively as heads (or concentrates) and tails. Some machines make what is called a three-part separation: giving heads, practically clean ore; tails, containing no ore worth recovery, and middlings, consisting of particles of ore with pieces of gangue adhering to them, and whose presence in either the heads or tails is undesirable. These are generally re-crushed and again treated.

The object of magnetic separation is to enrich a lean ore, or deprive a rich one of undesirable constituents, such as phosphorus, sulphur, titanium, silica, etc., or both. Some ores, when crushed, split up into pieces of all ore and all gangue, and are, therefore, easy to treat, but others refuse to do so, even when finely crushed.

The mineralogical composition of the gangue also has a great deal of influence upon the success of the operation, as the elimination of injurious ingredients depends upon their existing in non-magnetic forms. Thus phosphorus can be materially reduced and sometimes nearly eliminated, if it is present as apatite, as is almost universally the case with magnetites of the Appalachian System, but if combined with the iron this cannot be done. Again, sulphur may be present as pyrites, in which event it is rejected by the separator, or as pyrrhotite, which, being magnetic, goes into the concentrate.

Pyrites may be converted into pyrrhotite by roasting, as in one case that came under the writer's observation, where the ore

was roasted slightly to facilitate the crushing, which changed the pyrites almost entirely into pyrrhotite and caused it to be concentrated with the iron. This difficulty was overcome by roasting at the highest possible temperature, which decomposed the pyrrhotite, part of the sulphur being volatilized and the remainder oxidized to a basic iron sulphate, which is not objectionable in the blast furnace, as it is volatilized and goes off in the gases.

If an ore contains titanium as rutile or brookite, these may be separated with comparative ease, but if the titanium is present as ilmenite, it is very difficult, if not impossible at present to affect it.

It seems rather curious that the first account of magnetic separation in this country was for the purpose of getting rid of the iron ore. This operation took place near Port Henry, N. Y., in 1852, and the material used was the lean magnetic ore containing a large amount of apatite (phosphate of lime), the object of the separation being the concentration of the apatite for fertilizing purposes, and the iron ore was, therefore, a by-product. A description of this operation may be found in the *Trans. Am. Inst. M. E.*, Vol. XXI. The machine used at that time contained electro-magnets, excited by primary batteries, but proved too expensive for commercial success. Permanent magnet machines have also been used, but labor under the disadvantage that the strength of the magnets cannot be varied, and it was only when the dynamo made its appearance, furnishing electricity cheaply, that the magnetic separator became a commercial success.

The degree of intimacy with which the ore and gangue are mixed has considerable influence upon the success of the operation, as some ores are so intimately associated with their gangue that concentration cannot appreciably increase their richness, or in some cases, the amount of objectionable constituents present, such as phosphorus, sulphur, etc., cannot be sufficiently reduced. A case of the first kind happened in the writer's practice, where a Michigan ore contained extremely minute quartz crystals so intimately mixed with the ore that even when finely crushed it was practically unaffected. The second phase was nicely shown in a New York ore, where crystals of quartz were frequently found in the concentrates, with no magnetite attached that could be

observed by the naked eye. These crystals averaged from one-eighth to one-sixteenth of an inch in length, and about two or three-hundredths of an inch in diameter, and when examined microscopically always showed crystals of magnetite, extremely minute, included in the quartz crystals.

Many pieces of the same ore and of the same size showed the presence of three and sometimes four different minerals, thus proving the extreme difficulty of reducing the phosphorus to the Bessemer limit (one part phosphorus in 1,000 of iron), although it was an easy matter to concentrate the iron to sixty-five per cent. and over, starting with an ore containing about thirty-five per cent. iron.

The cost of crushing is the largest item in the expense account, and this alone often determines the commercial success of the operation. As shown above, the degree of comminution often depends upon the nature of the ore itself, but a large amount of crushing may be avoided by reducing the ore first to one-inch or three-quarters of an inch mesh, passing over the separator and re-crushing and again treating the tails. The size to which the ore is crushed is influenced, in many cases, by the prejudice of the furnace-man against fine ore, and ore finer than one inch mesh is not considered as desirable as larger sizes. That this is frequently a matter of prejudice is indicated by the experience in the use of concentrated ore at Scranton, Pa., in the furnaces of the Lackawanna Iron and Steel Company, under the management of the late Mr. E. S. Moffat, and the Port Henry, N. Y., furnace, managed by Mr. N. M. Langdon. The results obtained by both of these gentlemen appear in the *Trans. Am. Inst. M. E.*

The writer had occasion, in 1882, to make some very interesting experiments with a small model of the Anvil Furnace of the Pottstown Iron Company, in whose employ he was at that time, and among other curious facts it was demonstrated quite clearly that the distribution of fine ore in a furnace was governed principally by the size of the bell, but was also influenced by the fluctuation of the stock line, so that the writer has no hesitation in saying that with a correctly proportioned bell and the maintenance of the stock at the proper stock line any modern furnace should handle the ordinary concentrated ores crushed to three-

quarters of an inch or one-half of an inch mesh without the least difficulty.

There is another feature of the use of concentrated ore which I think has not received the attention it merits. In some cases the gain in the increased output and regular work of the furnace from the constant composition of the ore would be of great value alone. To illustrate more clearly, take the following facts. The ore of a large mine in the Eastern States, often smelted by itself, varies greatly in richness and the amount of flux required. This affects not only the yield of iron in the furnace, but also its grade, besides requiring more fuel and flux, and at the same time producing more cinder, which of itself is very undesirable. If such an ore were concentrated, the gain in regular running of the furnace would in some measure contribute to pay the cost of concentration, not to mention the saving of fuel, flux, etc.

There are many ores which, in their natural state, by reason of their leanness or the presence of impurities, cannot bear transportation, but would easily do so if concentrated. Hematite ores, as shown by the accompanying table, when rendered magnetic and separated, give very encouraging results, which lead to the belief that the process will be applied to many of these ores in the near future, thus opening up a practically new ore field.

After having performed the separation, the question arises, what is the efficiency of the machine? This is frequently a very difficult question to answer, and is often complicated by commercial and chemical considerations. In every operation there is a point beyond which it does not pay to go, as the value of the material recovered is equal to, or less than, the cost of treatment. This point will vary for different ores, and when it is determined for any one ore, the operator must be content. If the ore is not very intimately mixed with its gangue, the loss may be reduced to a very low figure, but if this is not the case, the loss may be quite high.

It is manifestly unfair to charge the separator with all the iron in the tails, unless it is present in a magnetic condition, and on the other hand it sometimes becomes extremely difficult to determine the amount of magnetic iron, owing to the other minerals present. It has been the practice of the writer to consider all

iron soluble in boiling hydrochloric acid as magnetite, and this, while not absolutely accurate, gives satisfactory results for the large majority of ores, except in the case of those rendered magnetic by artificial means, such as hematites. As an illustration of the difference between the total iron in the tails and that soluble in boiling acid, it was found at the Tilly Foster Mines that the average difference in six months' work was a little over two per cent., the actual difference being probably twice this figure, as the tails carried many minerals containing iron in a non-magnetic form, but soluble in the acid, and thus raised the figure for soluble iron.

All the machines now in use are more or less efficient, and the proper machine for a given ore will depend upon the ore itself. If easily separated from its gangue almost any machine may prove satisfactory, but if very intimately associated, one machine might do better work than another.

A convenient formula for calculating the amount of crude ore required to produce a ton of concentrate has been published by Mr. Henry Helms, of Port Henry, N. Y. The writer had occasion to derive this formula about two years ago, in order to convince a client of its mathematical accuracy, and it is now given in full.

Let

$C =$ percentage of iron in the crude ore.
$H =$ " " " " " heads.
$T =$ " " " " " tails.
$X =$ number of tons of crude per ton heads.
Then $XC = H + (X-1)\,T$,

and

$$X = \frac{H - T}{C - T}$$

$$H = XC - (X - 1)\,T$$

$$T = \frac{XC - H}{X - 1}$$

$$C = \frac{H + (X - 1)\,T}{X}$$

$$\text{Per cent. loss} = \frac{(X - 1)\,T \times 100}{XC}$$

The following examples will illustrate the use of this formula :—

Example from Chateaugay Tails.

Crude, ...19.60	19.60	60.48
Heads, ...60.48	— 8.96	— 8.96
Tails, ... 8.96	10.64)	51.52 (4.842

$4.842 \times 19.60 = 94.9032$

$3.842 \times 8.96 =$ 34.42432

$1. \times 60.48 =$ 60.48

94.90430

$$\frac{34.42432 \times 100}{94.9} = 36.2743 +$$

Crude, ...11.80	11.80	68.365
Heads, ...68.365	4.33	4.33
Tails, ... 4.33	7.47)	64.035 (8.572 +

$8.572 \times 11.80 = 101.1496$

$7.572 \times 4.33 =$ 32.78676

$1. \times 68.365 =$ 68.365

101.1496   101.15176

$$\frac{32.78676 \times 100}{101.15} = 32.\ 4 \text{ per cent. loss.}$$

Example from Port Henry Ore.

Crude, ...64.2	64.2	71.2
Heads, ...71.2	9.	9.
Tails, ... 9.0	55.2)	62.2 (1.126

$1.126 \times 64.2 = 72.2892$

$.126 \times 9. =$ 1.134

$1. \times 71.2 =$ 71.2

72.2892   72.334

$$\frac{1.134 \times 100}{72.3} = 1.56 \text{ per cent. loss.}$$

From these examples it is readily seen that the percentage of iron in the tails is not a measure of the efficiency of the separation, and until the above calculation is performed it is hardly feasible to intelligently criticise the results.

In investigating, by Helm's formula, the analyses of many ores, separated by different machines and analyzed by several chemists, it will be seen that only exceptionally do the results balance, which is undoubtedly due to difference of sample, and shows the impossibility of absolutely correct sampling in the material.

As an illustration the following results are given :—

Mesh.	Crude.	*H + I.*	Element.	
—	2.099	2.467	*P*	+
—	1.699	1.921	*P*	+
No. 20	0.0368	0.0374	*P*	+
" 10	0.237	0.0187	*P*	—
" 8	0.928	0.922	*P*	—
" 6	0.0488	0.058	*P*	+
" 10	1.59	1.68	*P*	+
" 6	1.561	1.774	*P*	+
—	0.0226	0.0228	*P*	+
—	2.736	1.402	*P*	—
" 10	20.235	19.940	$Si\ O_2$	—
" 20	22.049	21.760	$Si\ O_2$	—
" 10	0.593	0.680	*S*	+
" 20	0.688	0.775	*S*	+
—	0.757	1.063	*P*	+
—	1.534	2.687	*S*	+
—	60.75	59.25	$Si\ O_2$	—
—	77.21	75.03	$Si\ O_2$	—
—	0.794	0.578	*P*	—
—	0.588	0.677	*P*	+
—	1.082	2.245	*S*	+
—	1.705	2.430	*S*	+

The next table shows the analyses of heads, tails and crudes, also value of X and per cent. loss for a number of different ores. It will be noticed that the loss is quite variable, and that it is hardly possible to estimate it without the use of this formula, as in many cases, while the percentage of iron in the tails is comparatively high, the percentage of loss may be quite small.

Per cent. iron in crude.	Per cent. iron in heads.	Per cent. iron in tails.	Tons *C* per 1 ton *H.*	Per cent. loss.	
26.80	50.19	11.53	2.53	26.0	
28.28	51.04	10.32	2.26	20.3	
27.55	49.14	10.21	2.24	20.3	
27.17	49.54	10.04	2.30	20.8	Average of a year.
27.38	49.44	11.60	2.346	23 0	" " " "
42.99	69.86	7.95	1.767	8.0	
37.968	64.554	13.207	2.073	18.0	
31.28	62.56	4 66	2.175	8.0	
36.48	65.56	14.31	2 31	22.2	
36.48	58.78	22.16	2.557	37.0	Fine, jigs.
37 97	64.72	11.04	1.993	14.4	Coarse, jigs.
39.507	59.688	32.533	3.885	61.0	
40.16	55.12	15.913	1.617	15.11	
39.567	59.688	12.566	1.744	13.54	
53.20	69.90	7.67	1.213	3.8	
50.0	70.0	7.80	1.477	5.0	
52.2	66.8	18.70	1.435	10.8	
59.5	69.15	7.10	1.184	1.8	
62.0	70.90	9.25	1.168	2.0	
64.2	71.20	9.0	1.126	1.5	
19.60	60.48	8.96	4.842	36.2	Chateaugay tails.
11.80	68.365	4.33	8.572	32.4	" "
53.0	62.303	22.5	13.05	9.92	

The next table shows the same features as the previous one, except that the material under consideration is not naturally magnetic, but has been made so. It is interesting in this connection to observe that the loss is quite low, but on the other hand the heads are not very rich, and the figures for phosphorus, sulphur, silica, etc., are not given.

The analyses in the above table were taken from a paper by Clemens Jones, in *Trans. Am. Inst. M. E.*, and worked up by the writer, who greatly regrets that the cost of the operation is not stated.

Crude.	Heads.	Tails.	X.	Per cent. loss.
20.30	46.32	5.21	2.724	16.2
33.55	48.63	2.56	1.486	2.4
31.31	48.87	5.20	1.67	6.6
39.84	51.29	5.0	1.328	3.0
42.55	55.36	5.76	1.348	3.4

In regard to the application of this formula to regular work the following figures are given, being a comparison between the values of X for Tilly Foster Ore, for four consecutive months, the first set from actual weights and the second set from samples of crude, heads and tails analyzed by the writer.

	Weights.	Analyses.	Difference.
	2.52	2.43	0.090
	2.36	2.292	0.068
	2.73	2.66	0.070
	2.76	2 626	0.134
Average	2.5925	2.502	

$$\frac{2.502}{2.5925} = 96.5 \text{ per cent.}$$

The close agreement between the weights and analyses seems to establish the accuracy of the formula. In actual practice the formula would be slightly changed by the loss of material in the form of fine dust, but the error thus introduced may be neglected without seriously affecting the result.

Many of the analyses given in the tables were taken from papers published by Messrs. Birkinbine, Jones, and the writer, in the *Trans. Am. Inst. M. E.*

DISCUSSION.

MR. JOHN BIRKINBINE.—The subject of the magnetic concentration of iron ore has received a large share of my attention, and while serving as Consulting Engineer for several parties who experimented largely in this specialty, opportunities were offered to see probably all of the forms of magnetic separators extant, the work also necessitating an investigation of the inventions of such apparatus as are recorded in the patent offices of this and other countries. It will probably be a surprise to many to learn that nearly 150 patents have been taken out in the United States for magnetic separators applicable either for the treatment of ores, or for other purposes where it is desired to remove magnetic from non-magnetic material. As will be expected, the large number of inventions cover great varieties of form and arrangement, some of which do good work under certain conditions, but are almost if not quite impracticable under others; some are quite crude, others well perfected. Some indicate good mechanical design, but an absence of knowledge concerning electro-magnetism; others suggest an intimate acquaintance with this subtle force, but a deficiency in mechanical knowledge; and another class, while passing muster upon both of these points, includes machines inefficient by reason of ignorance as to the requirements of a merchantable iron ore.

Practical application rapidly sifts out those which offer the best opportunities for successful work, and many of the inventions have never gone beyond models or plans. The forms of magnetic separators which are in use on a commercial scale do not number more than five or six, only a few of some of these forms having been put into practice.

While agreeing with Mr. Landis that the character of an ore, both physical and chemical, influences the results obtained, I believe that more depends upon the machine than would be assumed from his statement, and an experience during an extended series of practical tests, where different machines were placed under similar conditions, convinces me that it is well to consider each machine in relation to the material it is to treat and the work expected of it.

In concentrating any iron ore magnetically, the material after it is prepared for the machine must be considered as consisting of, first, the pure magnetite or magnetized ore; second, the gangue, practically free from magnetic material; and third, a more or less intimate admixture of gangue and magnetite, which must either be carried into the concentrates or heads, reducing their richness or thrown aside with the refuse or tailings, increasing the amount of loss. In each individual case it is necessary to determine the economic limit, which prescribes how much of this mixed material or middlings can be permitted to depreciate the concentrate, or how much can be refused and cast aside with the tailings or submitted to subsequent retreatment. In most of the machines now used attempts are made to secure the three products separately, so that the middlings or mugwump can receive subsequent treatment.

It is not surprising that blast furnace managers whose experience has been entirely with lump ore and who have found more or less difficulty in treating the fine lean ores which have been delivered to the furnaces, should look with suspicion upon employing a liberal amount of ore which has been comminuted, even if it carries a considerable percentage of iron. Much of the annoyance which fine ores have caused, however, has come from what may be considered as fine dirt; the low grade ores encouraging charging furnaces with a large quantity of foreign material which was of small size. The experience of some Western furnaces, however, using the soft ores of the Lake Superior Region, has shown a preference for these, which, though finely comminuted, are rich in iron, and the prevailing character of the ore won from the Mesabi Range in Minnesota is practically a fine iron oxide sand. The employment of these Western ores and the comparatively extended use in late years of concentrated magnetic ores in the East, has done much to overcome prejudices, if they may be so called, arising from the use of fine, though lean ores, in blast furnaces whose equipment of engines and boilers are taxed to their capacity during ordinary operations. Magnetic concentration, if well carried on, produces an ore rich in iron, and with a small percentage of earthy impurities; it therefore requires a minimum amount of

flux, and if properly fed to a well-proportioned blast furnace, the particles of ore being small and of a practically uniform size, should yield more rapidly and readily to the reducing gases. As a result, a furnace of a given size should be able to produce more iron with a smaller comsumption of fuel per ton of product when using concentrated magnetite than when employing lump magnetite, and I believe it practicable to design a blast furnace of moderate size capable of using a charge made up of all concentrated iron ore (if this concentrate is not so rich as to be deficient in cinder-making material), which will produce as much iron, with possibly a saving of fuel, as would be obtained from a larger plant working on lump ores.

To the question which will naturally occur, does the magnetic concentration of iron ore pay, answers both affirmative and negative can be given. Within late years a large amount of money has been expended in perfecting machines, erecting works, and experimenting with various details. I feel confident that this expenditure has not met with satisfactory returns as a whole, and on the other hand, I am equally certain that magnetic concentration has paid in some instances. Although the process is not new, it had to be adapted to present conditions; in some cases more was expected of it than was just. The most difficult problems of treating very lean ore which had to be crushed to extreme fineness by untried machinery was attempted on a large scale; it would apparently have been better to have made the first effort with material easier of treatment; and after the machinery and appliances had been thoroughly tested, attempted the more difficult task. In other cases fire destroyed works just as those in charge were surmounting the difficulties following any new installation. In two other important instances financial disaster from outside causes crippled the industry just as satisfactory results were believed to have been reached. To-day the concentration of magnetic iron ores is carried on successfully and on a liberal scale by works adapted to do this, either by magnetism or by jigs working by gravity.

To make an iron ore concentrating plant successful requires: first, a thorough study of the physical and chemical composition

of the ore to be treated, and a knowledge of the amount and cost of such ore as is obtainable; second, a plant arranged to comminute, size, and deliver ore to separators with the least outlay for power, labor and repairs; third, concentrators adapted to the particular requirements operated by persons sufficiently familiar with mechanics and electro-magnetism to secure the best results; fourth, a market for the product which will absorb it in competition with other ores in such quantity and at such prices as will permit of its being delivered to points of consumption with a profit.

Magnetic iron ore generally occurs in connection with rocks of a character requiring to be blasted, and which are difficult to break with sledges or hammers; therefore, as a rule, a concentrating plant erected to use the material from a given mine or mines, must embody crushing machinery of sufficient capacity to handle large lumps, and if the primary crushers are worked fully the machinery which treats these broken lumps must be sufficient to handle what the crusher can supply, or else the work will be intermittent. The generally hard character of the gangue or rock accompanying the hard ore rapidly wears out all surfaces with which it comes in contact, such as crusher jaws, roll shells, conveyor chutes, screen-plates, etc., and the dust produced (particularly if dry crushing is resorted to), affects all shafting, gearing and other machinery. This heavy wear and tear necessitates the maintenance of duplicate parts, and to get good results, practically continuous operation is necessary; hence it is evident that concentrating plants of small capacity are at a disadvantage when compared with those of large output. I do not mean to say that small concentrating plants cannot be made profitable, but I believe in a majority of cases the larger the plant, the better the chances for success are, provided the supply of crude material is ample, and cheaply won, and a good market can be obtained for the finished product. With a works of large capacity, labor-saving devices for winning the crude ore, and conveying it to the concentrating plant, can be introduced. The equipment of the plant can include many duplicates without increasing its cost proportionately, and appliances for handling can be used which might not be economical in a smaller enterprise, while the salaries

of skilled help required, and the outlay for fixed charges, would represent a smaller amount per ton in a large than in a small plant.

Mr. Landis has called attention to the fact that certain combinations of sulphur or titanium in iron may or may not be found with the concentrates, and these statements suggest the possibility in the future of adjusting the strength of the current used to the velocity of revolution or of gravity, so that minerals possessing different degrees of magnetism could be separated from each other. In other words, may it not be possible, as our knowledge in this speciality increases, to so adjust the forces in the machine used as to distinguish between magnetite, ilmenite, and pyrrhotite, all of which are now considered as going into the concentrate?

Mr. C. T. Thompson.—I think that perhaps the most important point in the whole process is in the sampling, as it seems almost impossible, unless very great care is exercised, to get samples of anything like a uniform quality.

Mr. Landis.—I would also call attention to the fact that the microscope plays a very important part in this operation. In one case, for example, the concentrates carried very small fragments, which were discovered under the microscope to contain pyrrhotite because of the attraction which the magnet exerted upon them. I have also noticed that lately a combination of jigging and magnetic separation has been applied in Missouri with considerable success, the part that could not be separated by jigging being taken out quite thoroughly by the magnetic method.

Mr. Henry G. Morris.—I would like to know if there is any machine for separating the ore by centrifugal force?

Mr. Thompson.—There is, I believe, a patent on a device, which consists of a conical revolving-plate, with a coil below it, but I have never heard of its practical use.

V.

THE NEW FALLS OF SCHUYLKILL BRIDGE OF THE PHILADELPHIA & READING R. R. CO.

By W. B. Riegner, Active Member of the Club.

Read, February 17, 1894.

The following brief description of the construction of the Reading Railroad Company's new bridge at Falls of Schuylkill, Philadelphia, is presented merely as a matter of local interest, and not because any unusual difficulties were met with in its construction. The work was of ordinary character, except possibly the method of coffer-damming.

The principal object in building the bridge was to provide a direct connection for trains running between Wayne Junction and the junction of the Reading and Baltimore & Ohio roads at Girard Avenue station. Previous to building the bridge, these trains were run backwards between West Falls and Nicetown, and also had to be run into the yard at West Falls, both undesirable operations. The new bridge permits trains to run through head-on, and also keeps them entirely out of West Falls yard.

The bridge consists of an 80-feet stone arch over the East Park drive, and 8 deck-plate girder spans, one of 60 feet, one of 92 feet, and six of 87 feet, center to center of piers,—over the river and adjacent low ground and West Park drive. The bridge carries two tracks, 13 feet center to center. The alignment is a 6-degree curve and the gradient is 0.25 per cent. rising to the eastward.

Foundations in the River.

The river piers were founded upon the rock bed of the river. A floating coffer-dam was used for this purpose, entirely similar to one used some years before for removing rock obstructions from the canal channel, by Mr. E. F. Smith, member of the Club, and described by him in No. 4, Vol. IV, of the Club Proceedings. When in position for work, the dam is rectangular in shape, 62 feet long by 36 feet wide—outside dimensions—and 16 feet high.

Each side consists of timber crib work 10 feet wide, making the inside dimensions 42 feet by 16 feet. At each corner there is a movable timber extending vertically from the bottom of the crib to some distance above the top. These timbers or spuds are shod with iron on the bottom, and serve to hold the dam in position while the sheet piling is being done.

The dam is divided vertically through each short side into two equal parts, which can be floated separately to any desired position and afterwards joined together. Water-tight compartments are built in each section to assist in floating it, and these compartments are also used to hold stone when it is desired to sink the cribs.

The method of working the dam is as follows:

When the two sections are united and placed in required position, the spuds are dropped and the crib work is sunk by letting water into the water-tight compartments, and putting in the necessary amount of stone. Any irregularity in bearing between the bottom rock and bottom of crib is then corrected by a submarine diver, who blocks up where required. Close sheet piling of jointed plank three or four inches thick is then put on the outside and spiked to the cribs. Puddle, composed of clay and gravel, is thrown around the bottom outside, and the dam is ready to be pumped out. On account of the length of the dam, 42 feet inside, two sets of braces were put across from side to side as the water was pumped out. When the masonry reached the height of the braces, they were taken out and the dam braced against the masonry.

The maximum depth of water encountered at Falls bridge was 13 feet at ordinary water level. Several freshets occurred during the progress of the work which did some damage to the dam. At one time, when a dam was ready to be pumped out, a rise in the river moved it down stream about thirty feet, tearing off the sheet piling. It was drawn back to place and successfully completed. To make a complete shift of the dam from one pier to the next, with a gang of six men, required about six or eight days, divided as follows: To take the dam apart and reset it, about three days; to sheet pile, about two days; to puddle, about one day; and pumping out and puddling meanwhile required

about one to two days, depending on the amount of the leakage. At each shift a portion of the plank sheet piling, perhaps ten per cent., had to be replaced by new stuff. The pump used was located on a small steamboat, and was run by a steam engine, The amount of pumping required after the dam was once pumped out, varied for the different piers; some dams requiring little pumping and others a good deal. But one of the foundations required much leveling off of the river bed, and this one also gave considerable trouble to keep the water out; but the leaks were finally stopped by using gunny bags around them, the bags being drawn into the crevices by the force of the water, thus holding the puddle.

The floating dam was used for the three piers in the river channel, the two piers near the shore being put in with ordinary dams. The floating dam is still in good condition and could be used again if needed. The original dam, of which the one used at Falls bridge is an enlarged copy, was used for twenty-three or twenty-four settings.

The Iron Superstructure.

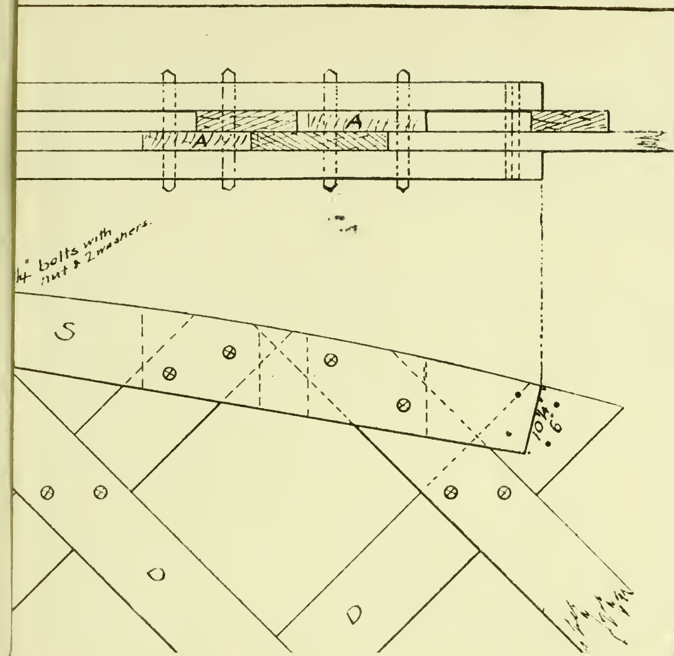
As before stated, this consists of eight double-track deck-plate girder spans, varying from 60 feet to 92 feet in length, center to center of piers. The metal is wrought iron; no steel being used. The girders are all 90 inches deep out to out of angles, and are, on account of the curvature, spaced 8 feet centers under each track, instead of the usual P. & R. standard of 6 feet. The bed-plates on the piers are continuous under the bearings of the adjacent spans for each line of girders, in order that the force developed by the expansion and contraction of the girders will be transmitted through this plate, and not through the coping. A solid plate floor with stone ballast was put on the 92-feet span over the west drive, to comply with requirements of the Park Commissioners. This was made of Pencoyd trough-shaped sections; section B, 53 pounds per yard, equal to 27.6 pounds per square foot of surface covered. The other spans have P. & R. standard wooden floor, 9 inches by 12 inches by 12 feet yellow pine ties, spaced 16 inches center to center. The 4 inches superelevation of outside rails is made by blocks on top of the ties. Speaking

generally, the iron work is the usual plate girder construction designed for 125-ton engines.

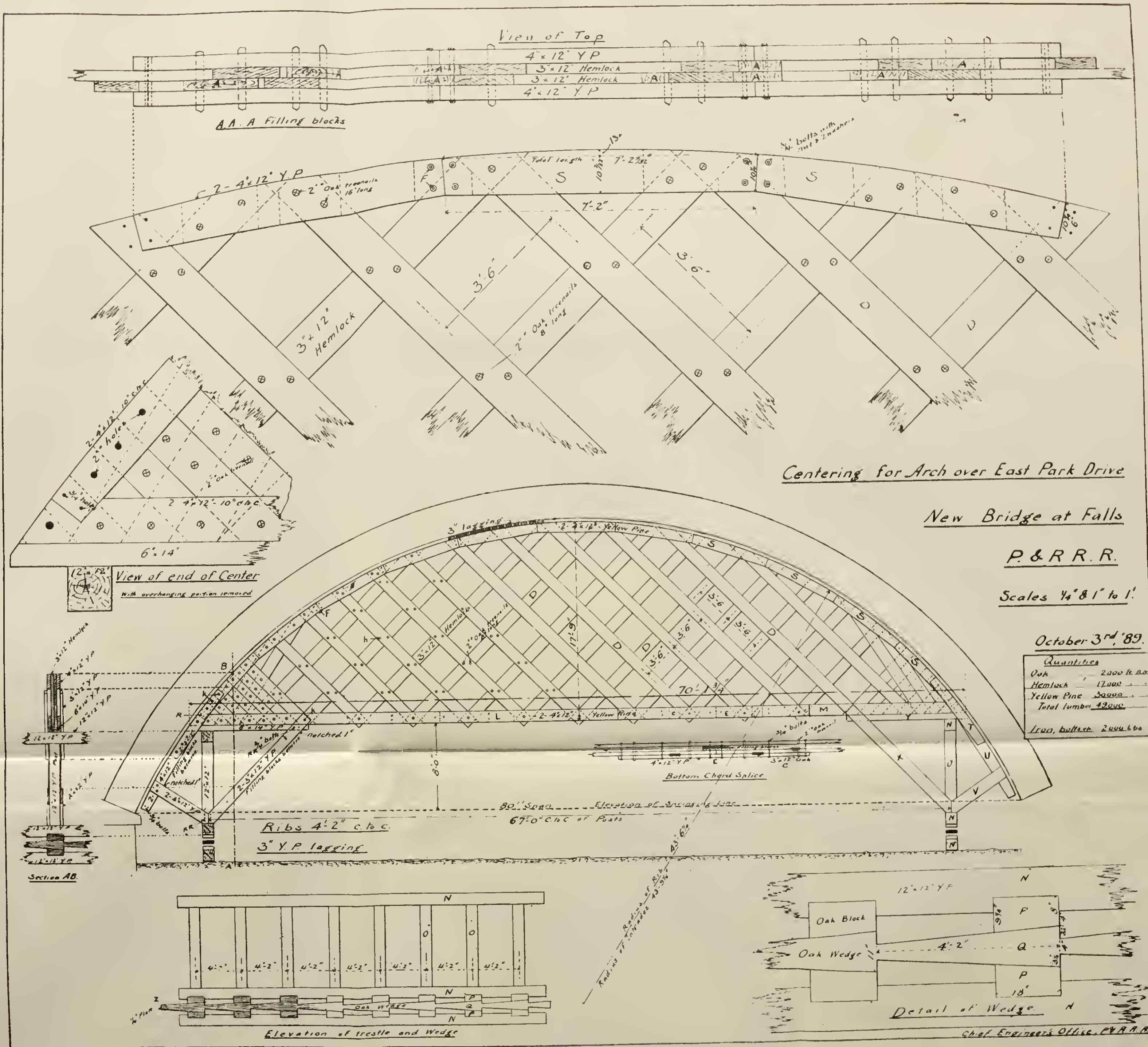
The span over the East Park drive is a stone segmental arch of 80 feet span and 26 feet rise. It is the longest arch span on the Reading Railroad, though only 2 feet longer than the spans of the adjacent skew arch built in 1854, which are 78 feet. The ring has a thickness of 3 feet, both at the crown and springing line. The backing is covered with a 6-inch layer of concrete, and this by $1\frac{1}{4}$-inch layer of asphaltum, for the purpose of preventing leakage through the arch. This has been fairly successful, though there is a slight leakage under the haunches. The surface water on the west half of the arch is carried, by means of an iron pipe, through the north face of the arch, while that on the eastern half drains into the earth filling back of the arch. There is no earth filling above the arch.

The Center.

The center consists of eight ribs placed 4 feet 2 inches apart center to center, 17 feet 9 inches high and 70 feet long measured on the horizontal bottom chord. The center was so designed as to give a clearance of 12 feet over the Park drive, which placed the bottom chord of the ribs 8 feet above the springing line of the arch. The ribs thus did not extend the full length of the ring by about 10 feet on each side, so that it was necessary to attach an over-hanging portion to each end. The top and bottom lines of the ribs were each made of two 4-inch by 12-inch pine planks, 6 inches apart in the clear, to allow the 3-inch by 12-inch hemlock diagonal bracing to pass between them. All intersections were tree-nailed with 2-inch oak. The ribs were supported near their ends on two trestles 33 feet long, parallel to the springing line, 67 feet apart. These trestles contained the wedges for dropping the centers, one wedge in each trestle. The wedges were of oak, 34 feet long, made from 12-inch by 12-inch sticks, and bore against oak blocks set in the bottom sill of the trestle and in the mud sill. The wedges and bearing blocks were both greased when they were set up, in order to insure easy driving, when the centers were to be dropped. The plan of the center, on the accompanying plate, shows full details.


A
A
4" bolts with
nut & 2 washers.
S
10¼
6
D
D

RIEGNER—THE NEW FALLS OF SCHUYLKILL BRIDGE.



The method of setting the keystones was as follows: The stones were dropped into position and iron wedges were driven on each side, making an equal joint between the key and the adjacent stones. This joint was then filled with cement.

The center was dropped about two weeks after the keystone was put in, the entire masonry being in place at the time. The wedges were driven by striking them with a heavy piece of timber, handled by a number of laborers. Levels were taken on top of the key after it was set, and again shortly after the center was removed, to determine the amount of settlement. This was found to be one-eighth of an inch at one end and nothing at the other.

The total length of the structure from the west back wall to the east springing line of the arch is 769 feet. The height from the base of low rail to ordinary water surface is 47½ feet.

The stone used was principally Conshohocken, with some Leiperville and some Union Springs. The sheeting of the arch is trap rock, from Rock Hill, North Pennsylvania Railroad.

The work was commenced in May, 1889, and finished in February, 1890; considerable time having been lost by a change of contractors and by floods in the river.

The cost of the work was as follows:

The movable coffer-dam cost about $3,000 to build, including one set of sheet piling. The total cost for coffer-dams, including two crib coffer-dams, for the piers at the edges of the river, and pumping, was $14,000. The contract price for the arch was $15 per cubic yard, which price included furnishing the false works. The price for pier masonry was $12 per yard, exclusive of coffer-dams. The coffer-damming was done by the railroad company.

The entire cost of the bridge was about $175,000, including the short approaches.

DISCUSSION.

Mr. Henrik V. Loss.—Has there been any change in the curvature due to expansion?

Mr. Riegner.—I think not, though I do not know that it has been measured.

Mr. Edwin F. Smith.—The stone arch at Conemaugh, on the Pennsylvania Railroad, was semi-circular and had a span of 80 feet, and was one of the viaducts for the old portage road. After

the abandonment of the latter it was used for the main line. It was destroyed in the Johnstown flood.

Prof. Edgar Marburg.—I would like to inquire whether it is now the standard practice on the Philadelphia and Reading Railroad to use four instead of three girders on their double-track bridges, or whether the former was used in this case on account of curvature.

Mr. Riegner.—I do not recollect what was the principal consideration which governed the use of four girders in this particular case, but with four each track is independent, which is not the case with three girders, for then the inside one is subject to strain from travel over both tracks.

Prof. Edgar Marburg.—By the use of three girders, spaced $9\frac{3}{4}$ feet center to center, for tracks 13 feet center to center, a saving in weight of nearly 10 per cent. may be effected, though this depends, of course, to some extent on the specifications and loading. The total cost of workmanship in the former case will not be much greater than three-fourths of that in the latter, so that the net saving in material and workmanship may probably be fairly placed at about 12 per cent. This economical advantage is partly sacrificed through the added requirements for floor timbers. The cross-ties must be both larger and longer and their periodical renewal will tend to further reduce the relative economy as regards first cost.

I know of no constructive reason why four girders should be preferred to three, and unless there is some exceptional condition, such as curvature, it would seem better, on the ground of economy, to use three girders.

Mr. C. H. Davis.—The Baltimore and Ohio Railroad is now putting up three girders, 85 feet long, for double track, on a bridge at Harper's Ferry, which has been very carefully figured out for economy.

Mr. Robert Cartwright (*visitor*).—I recollect that on the Union Pacific and other Western roads, in past years, it was often necessary to use one track while the other was being built, and we also provided that one track must stand even if the other went down, and we used four girders. It is useless, however, to say that one form will be better than the other under all circumstances.

VI.

COMMENTS ON CURRENT PRACTICE IN THE DESIGNING OF PLATE GIRDERS.

By Prof. Edgar Marburg, Active Member of the Club.

Read, March 3, 1894.

It is well known that there exists among bridge engineers a great diversity of opinion in regard to the proper methods of proportioning plate girders. The best evidence of this may be found in a comparison of a few of our leading bridge specifications. The explanation is not far to seek. While theoretical considerations have contributed largely toward shaping existing methods of designing plate girders, yet, from the nature of the conditions involved—their complexity and their manifestly uncertain character—the matter lies, to a certain extent, beyond the reach of a purely rational treatment.

Experiments in this connection are greatly needed, and until they have been made, certain features of design must continue to furnish legitimate ground for differences of opinion. In order that experiments in this field may have sufficient weight to influence conservative practice, they must be conducted on an extensive scale, covering, in a systematic manner, a wide range of conditions. Unless government aid can be obtained in carrying out such plans, it may be expected that their execution will be long deferred.

Very few tests of built beams have as yet been made in this country. A valuable series of experiments on thirty-two girders of this type was made in Holland in 1878–9,* and a few others have been reported within recent years in Austria and Germany.†

The foregoing experiments were all made on girders of moder-

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* "Principles of Economy in the Design of Metallic Bridges," by Charles Bender, C.E. (Appendix), or "Experiments on Steel and Iron Bridge Girders," *Railroad Gazette*, January 26, 1883.

† *Engineering News*, January 2 and 9, 1892.

ate size, chiefly with a view to studying the comparative behavior of different materials under varying conditions of workmanship. Though highly instructive in these respects, they throw practically no light whatever on the many important questions of design. The influence on the strength of a plate girder of such matters as thickness of web, size and spacing of stiffeners, character of splices, eccentricity of flange stress, etc., is scarcely better understood to-day than it was fifteen or twenty years ago. Practice has undergone certain marked changes during this period, but the lack of uniformity at present is strikingly apparent.

It is proposed in this paper to direct attention to a few of the more important points of difference, in the hope that by their discussion some advance may be made toward arriving at a greater unanimity of opinion.

Nearly all specifications require that the web must be of sufficient thickness to fulfill two conditions:

1. The mean intensity of shear must not exceed a prescribed limit.

2. The bearing of flange rivets must not be greater than a specified unit value.

In addition to these, a common requirement is that the web thickness must in no case be less than a stated minimum.

The allowable unit stress for web shear is usually fixed at 4,000 pounds per square inch. The writer considers this value much too low. Ten or twelve years ago, values twice as great were commonly used, and that at a time when a minimum thickness of $\frac{3}{8}$ inch for web plates was seldom or never specified.

Mr. Bouscaren, in the latest edition of his specifications (1890), permits a unit shear on webs of 9,000 and 10,000 pounds for wrought-iron and steel respectively. The Pennsylvania Railroad specifications, and those of the Norfolk and Western Railroad, modeled on similar lines, contain no clause directly applicable to web shear. Otherwise, in most cases, 4,000 or 5,000 pounds is specified, usually the former. Cooper's specifications (edition of 1890) may be mentioned as a notable exception, in that the former requirement of 4,000 pounds per square inch has been cancelled, and the web thickness is now determined wholly by rivet bearing, $\frac{3}{8}$ inch being the minimum thickness allowed.

The writer knows no good reason for using as low an intensity as 4,000 pounds for web shear. In his judgment, this value may safely be doubled for a web that is properly stiffened. Can it be seriously contended that it is possible to produce failure in a plate girder of ordinary design through the shearing of the web plate? Has even incipient failure of the web, in any other manner than through buckling, been observed in experiments thus far made?

It so happens that for flange rivets arranged in a single line, with a minimum permissible pitch of three diameters and allowing 12,000 pounds for unit bearing, the required web thickness will be substantially the same as that found by using 4,000 pounds per square inch for web shear, as may be readily shown as follows:

The thickness t of web plate, as determined by rivet bearing, may be expressed in the form:

$$t = \frac{S\,p}{D\,b\,d}$$

in which $S =$ maximum end shear,
$p =$ minimum allowable pitch,
$D =$ effective depth of girder, in inches,
$d =$ diameter of rivets,
$b =$ allowed bearing per square inch.

If in this equation b is given a value of 12,000 pounds, then with $p = 3d$, there will result:

$$t = \frac{S}{4{,}000\ D}$$

or Dt, which expresses very nearly the area of the web, becomes equal to $\frac{S}{4{,}000}$.

If the data above assumed were general in their application, there would be no objection to the use of 4,000 pounds in shear, provided the purely conventional origin of such an apparently low unit were clearly recognized. With two lines of flange rivets, however, staggered in a pair of 6×6 angles, p may be reduced to $2d$ if necessary for bearing, in which case the resulting web area from the formula would be $\frac{S}{6{,}000}$ for $b = 12{,}000$, or $\frac{S}{7{,}500}$ for $b = 15{,}000$.

The writer believes that even the latter value, 7,500 pounds per square inch, is not excessive, and that the use of 4,000 pounds for unit shear involves frequently a considerable waste of material. For smaller girders the minimum allowable thickness, $\frac{5}{16}$ or $\frac{3}{8}$ inch, would have to be used in any case, but for larger girders an appreciable saving might be effected. This becomes greater, evidently, for specifications which allow 15,000 pounds for unit bearing and $\frac{5}{16}$-inch minimum web thickness, an extreme case being that of a double track through bridge consisting of either two or three girders and designed for heavy engines.

It is sometimes held that, since the shear is assumed to be borne wholly by the web, the intensity of the shear in the latter, considered as a rectangular beam, will be zero at the extreme fibres and equal to one and a half times the mean intensity at the neutral surface, the intensities at intermediate points varying between these limits as the ordinates of a parabola. In other words, that a computed mean intensity of 4,000 pounds per square inch would indicate a maximum unit stress of 6,000 pounds at the neutral surface. It may be readily shown, however, that in the case of a flanged beam such a condition cannot possibly obtain. A little reflection will make it clear that the resultant horizontal shear for any distance along the web, directly within the flanges, must be equal to the difference between the flange stresses existing at the ends of that distance, and, furthermore, that in the case of thin webs, the shear at the neutral surface for a corresponding distance will not be very much greater than this value. As the resisting moment of the flanges relative to that of the web is increased, the more nearly does the intensity of web shear approach a condition of uniformity. It may be said that ordinarily the maximum shear per square inch existing at the neutral surface will not differ essentially from the mean shear, as determined in practice by neglecting the flanges.

In regard to stiffeners, the greatest diversity of practice is again apparent.

In one class of specifications the well-known formula

$$s = \frac{a}{1 + \frac{d_2}{3{,}000\, t^2}}$$

is used for defining the allowable mean unit shear beyond which stiffeners are required, the enumerator a varying usually from 8,000 to 12,000.

According to other specifications, stiffeners must be used whenever the ratio of unsupported depth of web to its thickness exceeds a certain value, usually fixed at either 30 or 50.

The latter method must be regarded as wholly arbitrary, inasmuch as no account is taken of the relative shears at different sections of the girder. With a web of uniform depth and thickness, there is unquestionably more need of stiffeners near the ends, where the shear is maximum, than near the middle where the live load shear is only about one-quarter to one-third as great and the dead load shear is zero. The resulting inconsistency is sometimes lessened by permitting a greater distance between stiffeners near the center than towards the ends of the girder.

While the value of the formula used in the first method mentioned is unknown, in an exact quantitative sense, yet by its use the fact at least is recognized that the tendency to buckling is *some* function of the shear. The writer believes that, in the absence of experiments, it furnishes more consistent results than those found by any other method in use, and that a lower value than 12,000 need not be adopted for the numerator. This formula has been in use for many years, and experience has furnished ample proof of its safety. It does not deserve to be regarded, however, as other than a purely empirical expression, in which the constants have not yet been determined, even approximately. The theory by which it was derived is well known, although the extreme looseness of the hypothesis on which it rests is seldom fully stated or duly emphasized. The assumption that the web stresses may be considered as consisting of two sets of forces, tensile and compressive, making angles of 90° with each other and 45° with the neutral surface, holds good only along the latter surface, where the direct longitudinal stress from flexure is zero. At all other points of the web, the directions of the lines of principal stress are changed, owing to the influence of the longitudinal stresses, so that as curves, instead of straight lines, they finally become tangent and normal at the extreme fibres.

Although the existence of these longitudinal stresses may be ignored in practice, by neglecting the resisting moment of the web, the fact that they do exist and do exert an influence analogous to that described, is indisputable, though the ideal conditions may be seriously disturbed through imperfect splicing.

It seems evident, therefore, that in considering the web as composed of a series of hypothetical columns, with imaginary constant inclinations of 45°, and then applying Gordon's formula, the conclusions drawn from the assumption of these radically inexact conditions are not entitled to much confidence. It seems, in fact, highly probable that future experiments will show that the formula named cannot even be made to serve as a rational basis for a semi-empiric expression covering any wide range of values. Nevertheless nothing better is available at the present time, and there is but the choice of adhering to this formula, the results from which have, thus far, stood the test of service, or of depending wholly on individual judgment.

Theory indicates clearly that compressive and tensile stresses, normal to each other, co-exist at every point of the web, and the remarkably high resistances of thin webs are thus explained. Beyond this little is known, however.

If, in this formula, values of 12,000 and 4,000 be assigned to a and s respectively, the resulting value of $\frac{d}{t}$ will be 77. In other words, by the use of these units it is held that no web needs lateral support so long as the ratio of unsupported depths of thickness exceeds 77 and not necessarily beyond this point, since that is made dependent, and consistently so, on the shear. In the Pennsylvania Railroad specifications this ratio is placed at 30, regardless of the conditions of shear. These two examples probably represent the extreme limits of present practice. That the latter is needlessly low admits of no reasonable doubt. A strict compliance with this requirement would necessitate the use of stiffeners for 12-inch steel channels and 15-inch I-beams. The writer thinks, however, that a limiting ratio should always be specified, beyond which, even though the conditions of the formula are satisfied, stiffeners should be required, in order to insure the true vertical alignment of the web. This ratio should

probably not exceed 150, or perhaps 125 would be a more suitable limit.

As to the proper size of stiffeners, that is a matter concerning which absolutely no positive data are available. Precedent, and that of a most varied kind, is our only guide. It does not seem advisable, however, to specify any fixed sizes of angles, depending merely on the depth of the girders, for their thickness should be governed to some extent by that of the web.

In regard to the design of the flanges, practice is much more harmonious. The writer thinks that every specification should contain Mr. Cooper's excellent provision that at least half the flange area shall be of angles or else the largest sizes must be used. To prevent the excessive use of cover plates on the one hand and wasteful extravagance of material on the other, it would be difficult to devise any check more simple or satisfactory in its operation.

In the matter of unit flange stresses, the writer favors the use of 7,500 pounds per square inch for live and 15,000 pounds for dead stress, in proportioning the tensile flange; the compressive flange being made of the same gross section. It is noteworthy that certain specifications which use either this method, or fatigue formulas, in connection with the chord and web stresses of trusses, prescribe a constant unit stress for girder flanges, notwithstanding the fact that the value of $\frac{min}{max}$ flange stress may range from about zero to 20 per cent. The sudden change from a certain unit stress for spans under 20 feet in length to one 1,000 pounds greater, seems unscientific in principle and leads to the manifestly absurd result that, within certain small limits, a longer girder requires less flange area than a shorter one.

A clause to the effect that the compressive flange shall be stayed against lateral flexure at distances apart not exceeding 25 or 30 times its width, the writer considers should form a part of every specification. In connection with such a clause, the use of a modification of Gordon's formula, based on certain early experiments by Fairbairn, viz.:

$$s = \frac{a}{1 + \frac{l^2}{5{,}000\, w^2}}$$

which is often met with, appears unwarranted. When coupled with a second clause to the effect that at no time a larger value of s must be used than for a ratio $\frac{l}{w} = 12$, the formula only admits of an extreme variation of about 3 per cent. This formula, from the nature of its rational basis, is inapplicable to small ratios $\frac{l}{w}$, and such experiments as have been made on I-beams, some by Professor Burr* and others at Pencoyd, by Mr. Christie, indicate, for larger ratios, not only much higher values, but what is far more important, a totally different rate of variation, both for ultimate resistance and within the elastic limit. In these tests the compressive flange was given no extraneous lateral support whatever, while in practice it is securely held at panel points and, in the case of deck girders, at intermediate points to a considerable, though unknown, extent by the cross-ties. In the opinion of the writer, this formula is not only wholly unreliable, but serves no practical purpose when used in the manner indicated. The latter point is illustrated in an extreme degree in the latest specifications of the Atlantic Coast Line (1889), where, in connection with such a formula, it is specified that not only must the value of s never exceed that corresponding to a ratio $\frac{l}{w} = 12$, but the compressive flanges must be secured laterally at distances not exceeding this ratio. In their practical operation, these joint requirements reduce the allowable unit stress s to an absolute constant, about 3 per cent. lower than the numerator.

The writer thinks that the thickness of flange metal should be limited strictly to four times the diameter of the rivets for punched holes, and that in extreme cases of long, shallow girders, where this would not admit of flanges of the usual type, the holes should either be reamed or a different form of flange should be used. The latter plan is to be recommended, since, incidentally, the eccentricity of flange stress may thus be materially reduced.

In determining the bearing of flange rivets on web plates, the

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* "Tests of Wrought Iron I-Beams." Papers of Rensselaer Society of Engineers, Vol. I.

common practice is to neglect the component due to the vertical loading. The writer does not understand how, in the case of deck girders, this can be justified. If the uncertain element of friction between flange angles and webs deserves recognition, it should be accorded rather through an increase in the allowable bearing intensity. With girders only five feet center to center, it seems certain that the weight of a wheel concentration may be transmitted to the girder almost wholly through a single tie. In case the girders are spread 6.5 feet or more apart, the unequal deflection of the cross-ties may effect a more favorable distribution of the load, but it is not obvious how this may consistently be assumed to extend over more than about two feet of flange length for the case of a single concentration resting between two ties. This distance would include nine rivets at a three-inch pitch, so that for a 40,000-pound axle concentration each rivet would receive about 2,200 pounds. Assuming that, with $\frac{7}{8}$-inch diameter rivets and a $\frac{3}{8}$-inch web, the pitch named would give a bearing of 12,000 pounds per square inch for flange stress, the horizontal stress per rivet will be 3,900 pounds. This, combined with a vertical component of 2,200 pounds, gives a resultant stress per rivet of about 4,500 pounds, requiring a $\frac{7}{16}$ instead of a $\frac{3}{8}$-inch web. It would seem advisable to specify in general that the pitch in the loaded flange shall not exceed four inches.

As to allowing one-sixth of the web-section estimated in the flange, the writer thinks that this proportion should be reduced to one-eighth, to make due allowance for the weakening effect from rivets through stiffeners. Wherever the web is spliced, a suitable resisting moment should be provided for by attaching longitudinal plates, with a proper complement of rivets to the web, directly within the flange angles. Although this requires a somewhat greater amount of material than where flange cover plates are used for a similar purpose, the former arrangement provides for a more favorable transmission of the longitudinal stress at the joint and enables the web to discharge its functions as a beam in better conformity with the assumed conditions of perfect continuity.

There has been a well-defined tendency, within the past eight or ten years, toward the adoption of more exacting requirements

in respect to the designing of plate girders; this is attested in numerous ways, as, for example, by the increase in required thickness of web, size of stiffeners and laterals, diameter of rivets, the common use of fillers under stiffeners, the frequent neglect of the resisting moment of the web plate, etc. These changes are doubtless justified, to a considerable extent, by the great increase that has taken place within recent years in the weight of locomotives. At the same time, it deserves to be remembered that every added requirement affecting plate girders tends to encourage to that extent the use of short-span lattice girders.

The relative merits of plate and lattice girders have been made the subject of frequent discussions. Statements as to the span limits, within which the one or the other type may be considered preferable, do not convey a sufficiently definite meaning, unless qualified in respect to the contemplated loading—a matter which, singularly enough, is frequently overlooked. The force of this observation becomes apparent when it is considered that structures are proportioned at the present time for engine weights ranging commonly from about 80 to 125 tons; the extreme upper limit of current practice in this respect being represented probably by a pair of typical 135.5-ton locomotives.

Assuming, as a mean condition of loading, that specified by the Pennsylvania Railroad—namely, two 100-ton engines followed by 4,000 pounds per lineal foot—the writer holds that the use of lattice girders should not be permitted for spans below about eighty feet for single track and seventy feet for double track supported on three girders. Owing to their superior economy, lattice girders are not infrequently used, however, for single-track spans from sixty to eighty feet. Within these limits, cheapness is the only valid claim to be offered in their favor. It is well known that lattice girders are cheaper than plate girders, notwithstanding their usually somewhat greater cost of manufacture per pound. This is due to the fact that the economical depth of lattice girders is considerably greater than that of plate girders, thus leading to a proportionate saving of flange metal and to a net reduction of total weight more than sufficient to offset the difference in pound-cost of manufacture. The economical depth of a lattice girder is ordinarily fixed by certain practical considerations—namely, in

that it is the maximum depth which admits of shipment of the girder as a whole or in sections. Tunnels usually limit this depth to ten or eleven feet, back to back, of flange angles.

Now, with the assumed 100-ton engine loading, a sixty-foot deck lattice-girder bridge, eight or ten feet deep, can be designed in accordance with average first-class specifications for about 500 pounds per lineal foot, though even this weight may be pared down somewhat. The writer considers that a design so flimsy in its general character, embodying details, moreover, which are almost unavoidably faulty, deserves little short of unqualified condemnation. Its claim for consideration, in comparison with a plate-girder design, rests solely on a certain saving in first cost. And yet there are not only a good many such structures in existence, but their number is added to every year. It is true that a design of this kind may be made more tolerable by using a smaller depth, thereby increasing the size of the chord members and the lateral rigidity of the web system; but the relative economy would suffer in proportion.

The unfavorable features of short-span lattice girders are too well recognized to require any detailed notice here, and it may be said that efforts directed toward eliminating such features in part must be attended usually by a corresponding increase in cost. In case the matter of first cost is one of sufficient moment to apparently warrant the adoption of such structures, would it not be better, under these circumstances, to relax somewhat the requirements for plate girders?

To follow out the example before cited, a sixty-foot deck plate-girder bridge, loaded as specified, can be designed in accordance with average first-class specifications at a weight of about 650 pounds per lineal foot, or about 30 per cent. in excess of that mentioned for the lattice girder. This weight may be reduced, however, to about 525 pounds per lineal foot by lowering somewhat the usual requirements—that is, by permitting the use of a $\frac{5}{16}$-inch web plate, counting one-sixth of the web in flange area, reducing somewhat the size of stiffeners, omitting fillers at intermediate stiffeners, using top lateral and diagonal sway bracing only, allowing 15,000 pounds per square inch in bearing, etc.

The writer believes it must be conceded that such a design is

in all important respects preferable to the lattice girder before mentioned. In other words, it may then be stated, somewhat paradoxically, that, under certain conditions, a lowering of requirements will lead to a better structure at essentially the same cost.

DISCUSSION.

Mr. A. W. Barnes.—About three years ago an examination was made of the Filbert Street bridge of the Pennsylvania Railroad over the Schuylkill River. This was a two-track structure with three trusses, and the outside ones were found to be very much worn, probably because they got the full load and a double deflection and gave the sway bracing too great a load. It occurs to me that this same criticism may apply to plate girders supporting track under the same conditions.

In experiments made on the Lehigh Valley Railroad it was found that in from twelve to fifteen years the greater cost of maintenance of a three-girder bridge counterbalanced the extra first cost of one with four girders.

Mr. James Christie.—Twenty or twenty-five years ago plate girders were very uncommon, and lattice girders were generally used. The former were then spoken of disparagingly as a foreign type of construction, but they gradually came into favor, until now the condition first stated is almost reversed.

In the matter of the web, engineering experts have reduced its thickness almost to the condition of sheet-iron, and have yet maintained good results. In some local instances we have webs only $\frac{3}{16}$ inch thick, with wide flanges, and the present mean value is about $\frac{3}{8}$ inch for thickness.

Mr. Joseph T. Richards.—After considerable experience in bridge inspection, I find that the web always gives out first, even in cases where the flanges are thinner.

Mr. C. R. Grimm (*visitor*).—I would suggest the advisability of introducing into the floor system a series of horizontal diagonal bracing, crossing the panels formed between the floor beams. Such bracing would perform the important duty of transferring to the main girders, and through them to the abutments, any stresses tending to deflect the floor-beams horizontally.

Mr. John Birkinbine.—Mr. W. B. Riegner, in his paper on "The New Falls of Schuylkill Bridge," presented at the last meeting, February 17th, states that "the metal in the superstructure is wrought iron, no steel being used," and I have been told recently by a person who ought to know that one of our large railroads now requires all wrought-iron, no steel being allowable.

Mr. A. W. Barnes.—I think the Pennsylvania Railroad is the one insisting upon this; most of the others still allow steel I-beams.

Mr. Jos. T. Richards.—The manufacture and the use of steel are still in their infancy. It is coming in and iron is going out. Where the former is used it should be of good quality, and on account of the great variety of grades in which it is made we have found it difficult to get the best, and consequently do not consider steel to be reliable.

Mr. James Christie.—There is no doubt that the cheapening in its method of production has greatly extended the use of steel, but it must be remembered, in considering the quality of the metal, that the tests applied in these days are more critical than they were formerly, and the results on an absolute basis are undoubtedly better. I do not consider steel a fickle metal if it is properly made, as I believe it can be, and as tests can readily be applied to determine its quality, it would seem at least as reliable as iron.

Mr. John Birkinbine.—Is not the most important property in steel, its homogeneity, responsible for many of the defects which have developed? Good steel is now easier to make than good iron, for the former is made more mechanically. Statistics show that the great bulk of increase of production in recent years has been in steel, but that our production of rolled iron has been constantly advancing, though less rapidly than steel.

Mr. Jos. T. Richards.—If we look at the history of bridges, we notice that stone and timber constructions are old and proved reliable. Iron became the fashion, and then considerable time was spent on the form of the truss, many engineers adopting special forms for their own practice. Then followed the economy craze, which resulted in a good deal of trouble. England was the first to pronounce steel the best metal, and built the Forth

bridge entirely of this metal. They had considerable trouble, however, in getting the best quality. For example, one of the plates split while being unloaded before it was put into the structure. It was found that in shearing the edges they had been unequally strained, and this had caused the break.

It has also been observed that in straightening out steel-wire that had been coiled warm, it was very brittle and broke readily. These are a few of the many instances which make me consider steel a fickle metal.

Mr. J. S. Robeson (March 17, 1894).—In the discussion at the meeting on March 3d, Mr. J. T. Richards made some remarks on the use of steel for bridge construction which, I believe, fairly express the opinion of quite a number of bridge engineers, but which I think are somewhat misleading and in a certain degree incorrect.

Mr. Richards remarks, "And on account of the great variety of grades in which it is made we have found it difficult to get the best, and consequently do not consider steel to be reliable."

Simply because a material is made in a number of varying grades and qualities, seems rather a peculiar reason for calling it unreliable. I should consider, on the other hand, that such a fact would tend to increase its usefulness to the engineer, since he would consequently be able to procure with ease, metal of varying degrees of strength and elasticity for the differing members of his structure.

He further cites an instance of a plate, destined for use in the Forth bridge, breaking, and of wire, coiled when warm, being brittle. These are both examples of ignorant or careless work. In the case of the Forth plate it is known to-day that much of the material used in that bridge was of too high a tensile strength, and the vast knowledge of the treatment of steel that has been acquired during the past few years tends to prevent the repetition of such an occurrence.

In these days of the multiplication of tests it would seem, and I believe is, possible for the constructor to have exactly the metal furnished which may be called for in his specifications.

It is unquestionably true that the steel maker, in order to produce good and homogeneous material, must exercise more care

and have more knowledge than is ordinarly required for the making of iron. More care should also be taken in the shop treatment of the steel than is ordinarily used for bridge work.

The first steel that was used for construction purposes was very much harder than anything that is used to-day. A glance over the specifications for this class of material will show that each year, as the knowledge of the advantages and disadvantages of steel increased, softer and softer metal was demanded. In the harder grades there is much more danger of setting up dangerous internal strains by careless or ignorant work in shearing, punching and joining than in iron. This danger was augmented in the beginning, owing to the workmen being accustomed to handling iron, which even the strongest friend of steel will admit, will pass unharmed through barbarous treatment that would ruin the latter metal.

The specifications of to-day, even call for a metal that as a rule is too hard to give the best results. It is liable to be injured in the first place, in the rolling mill; secondly, by the bridge builder, and thirdly, will have its physical structure more quickly altered by the vibrations in the finished structure than a softer steel.

The use of steel for construction purposes, in bridges, buildings and boats is much more universal in England and on the Continent than it is here, and it is but fair to presume that this wider use must have brought greater knowledge regarding its properties than we possess. On the Continent—I cannot speak with as much certainty of the English requirements, but I believe them to be similar—a much softer steel is used than has ever been put into structural work here.

This metal has an ultimate strength not exceeding 60,000 pounds per square inch, and averaging nearer 57,000 pounds, an elongation of about thirty per cent. and a reduction of over fifty per cent.

Steel of this character has many advantages. It is almost impossible to harm it by careless or ignorant shop work, unless it be burnt, and that is difficult since it will stand a very high degree of heat without injury. It is more nearly homogeneous than steel containing greater percentages of the metalloids and

manganese, since in order that it may be soft enough to give these tensile results it must be low in these impurities, and such segregation (this being the greatest cause of heterogeneousness) as does take place cannot raise the obnoxious elements to such an extent in any one spot as to give disastrous results.

I have before spoken of the danger of harder steel being injured in the rolling mill, this softer material is again less liable to receive harm there, for the same reasons that apply to shop work.

It is not my purpose here to go into all the details of these reasons, for that would make a very long story, but simply to draw the attention of Mr. Richard's and other engineers to the fact that steel, much softer than the existing American requirements call for, is successfully used for structural purposes, and to my belief that such a material properly made would do away with the objections that he, in common with many others, urges against steel and would give him a metal somewhat stronger than iron, more reliable because more homogeneous, and for economical reasons eminently suited for structural work.

Prof. Edgar Marburg.—My views, as expressed in part at the last meeting, are in accordance with those of Mr. Robeson. I consider steel a good metal to use for plate girders, if we keep in mind the fact that the dangers that have been spoken of may be eliminated by using metal of proper softness, and by making tests to determine this property.

VII.

THE OLD VIADUCT BRIDGE OVER THE CONEMAUGH.

By J. Chester Wilson, Active Member of the Club.

Read, March 3, 1894.

During the discussion following the presentation of a description of the new Falls of Schuylkill bridge by Mr. Riegner, at our last meeting, reference was made to the old stone arch bridge on the Conemaugh River. This brought to my mind the fact that I had some description of the latter which might be of interest to the members of the Club, hence the reason for introducing it this evening in an apparently disconnected way.

Concerning the rainfall which was the first cause of the destruction of the Old Viaduct bridge, the water-shed which supplied the South Fork Dam, includes about forty-nine square miles; this area was included in the general district of the gigantic rainfall which averaged about eight inches, falling on an area of more than 12,000 square miles, and covering the mountain plateau and its eastern shed, from Johnstown to Harrisburg, and extending northward from Somerset to Tioga County. The greatest fall of rain at this time was oval in form, the north end being the wider as it reached up the north branch of the Susquehanna, as illustrated by the rainfall map of Pennsylvania for May 30, 1889. The immediate cause, however, of the destruction of the Conemaugh Viaduct was the bursting of the South Fork Dam.

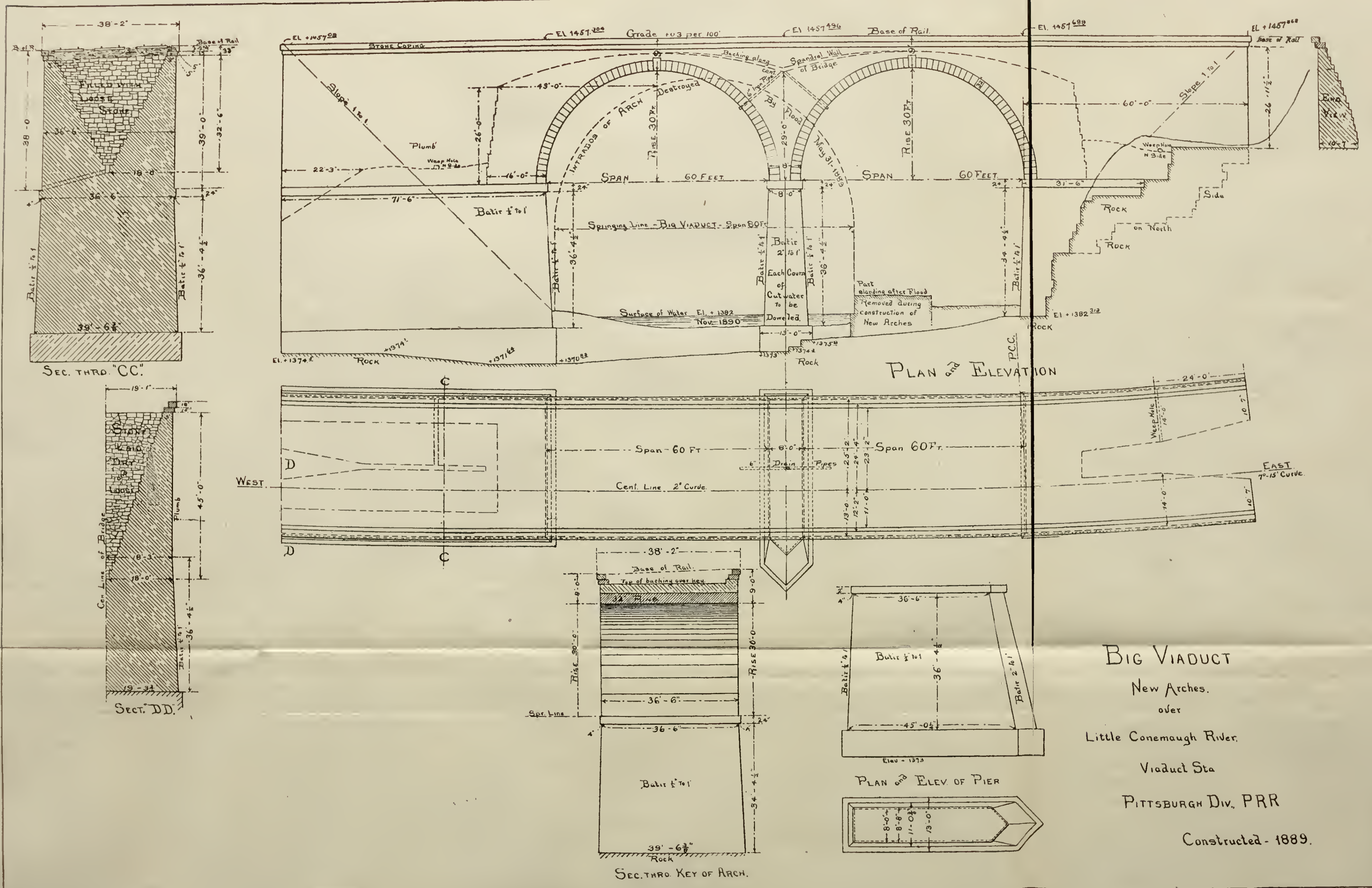
The old Portage Railroad was begun by the State in 1831, and to enable the construction of this line by the shortest route passing a point about eight miles east of Johnstown, the Horseshoe Bend or Conemaugh Viaduct was built across the stream and saved two miles which would have been necessary had the stream been followed westward. Until this arch was destroyed, May 31, 1889, it was the only structure of the old Portage Railroad remaining. It was my fortune to visit the spot, in an outing tour, just one year prior to the rainstorm and floods which destroyed this

bridge. On this visit, June 1, 1888, the photograph was taken, which is the original of my first lantern slide.

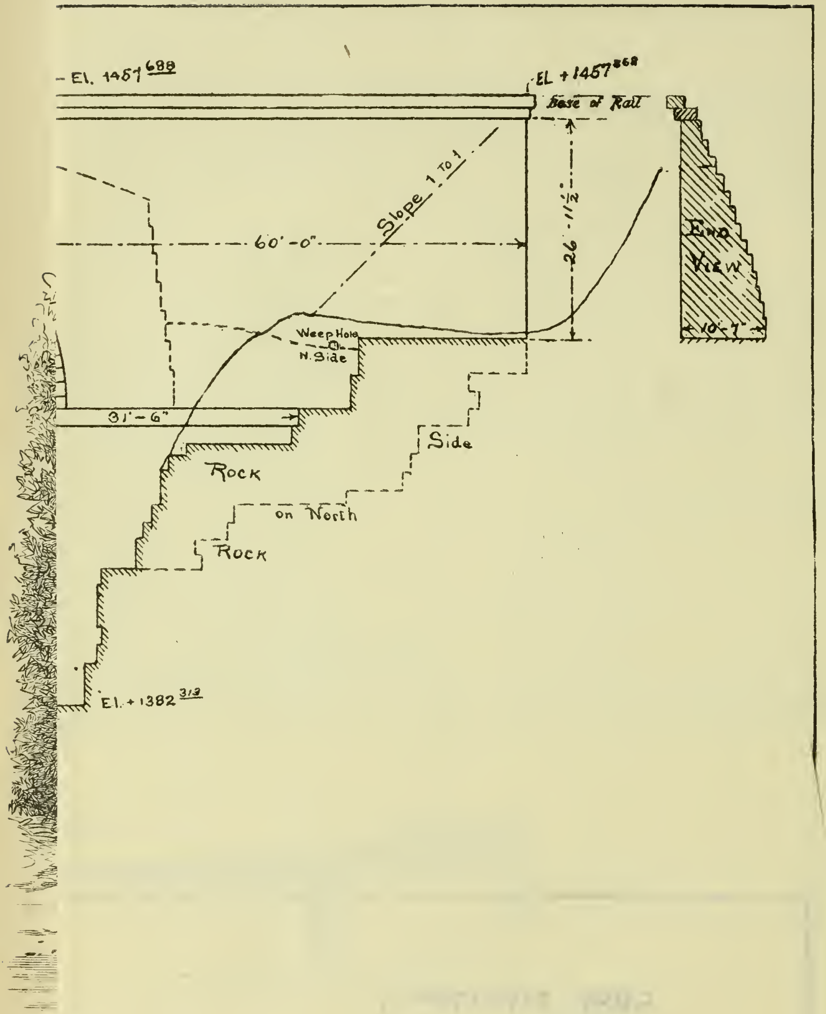
Solomon W. Roberts, C. E., says in the *Pennsylvania Magazine*

THE OLD CONEMAUGH VIADUCT. (Destroyed by Flood, May 31, 1889.)

of 1878, he was in charge of the locating party in 1831, and designed and superintended the erection of this arch. The work was done by a Scotch stonemason named John Durno. (Mr. Roberts adds that he was an honest Scotch stonemason,



Big Viaduct
New Arches.
over
Little Conemaugh River.
Viaduct Sta
Pittsburgh Div., PRR
Constructed - 1889.
Plan and Elevation
Sec. thro. "CC."
Sect. "DD."
Sec. thro. Key of Arch.
Plan and Elev. of Pier
Grade +0.3 per 100'
Base of Rail.
Stone Coping
Spandrel Wall of Bridge
Intrados of Arch Destroyed By Flood May 31, 1889
Rise 30 Ft.
Span 60 Feet.
Springing Line - Big Viaduct - Span 60 Ft.
Slope 1 to 1
Surface of Water El. + 1382 Nov. 1890
Part standing after Flood Removed during construction of New Arches
Each Course of Cutwater to be Doweled.
Filled with Loose Stone
Stone Laid Dry or Loose
Batir ¼" to 1'
Rock
West
East
Cent. Line 2° Curve
Span 60 Ft
Drain Pipes
End View
Weep Hole
Plumb



El. 1457 688
EL + 1457 868
Base of Rail
Slope 1 to 1
60'-0"
26'-11½"
End View
10'-7"
Weep Hole
N. Side
31'-6"
Side
Rock
on North
Rock
El. + 1382 313

which is probably no reflection on Scotch stonemasons, but is explained by his statement concerning the construction of the Portage Railroad in the same article, when he says: "The Canal Commissioners were politicians. There was great competition for contracts, and work contracted for at low prices often failed to endure the strain to which it was subjected, the laws of nature having no respect for political parties.")

Mr. Roberts' description further states that this arch was a splendid and imposing piece of masonry about 70 feet high, with a semi-circular arch of 80 feet span, $3\frac{1}{2}$ feet thick at the springing line, and 3 feet at the crown. The arch stones were light-colored sandstone, and the backing of silicious limestone found near the spot. The sandstone was split from erratic blocks, often of great size, which were found lying in the woods on the surface of the ground.

The contract price for the masonry was about $4.25 per perch of 25 cubic feet, and the work remarkably well done. The face stones were laid in mortar from the silicious limestone without the addition of any sand. The cost of this construction was about $55,000.

After the destruction of this arch by the floods in 1889, the Pennsylvania Railroad Company constructed a new two-arch stone bridge, each arch having a span of sixty feet. Details of the new bridge are shown in the accompanying plate, also the position of the old viaduct in relation to that of the new work. As shown in the drawing, the new spans taken together are considerably wider than the old single span. This was made necessary on account of the heavy washing-out of the east bank of the river during the flood.

DISCUSSION.

The Chair invited Mr. George B. Roberts, President of the Pennsylvania Railroad Company, to address the meeting upon this subject.

Mr. George B. Roberts.—In 1831, when the Conemaugh Viaduct was built, it was considered one of the handsomest stone arches in the country.

Regarding what has been said respecting the relative merits of iron and steel, it may interest you to know that the rails for the old Portage Road were made in England, and were ordered of short lengths, so as to go around curves without bending, which it was feared would cause them to break. And these were iron rails.

If I may say a few words in discussion of Prof. Marburg's paper, I will remind you that steel, in its manufacture, is in the first place iron, which must be of good quality if the finished product is to be reliable. I think it is a fact, however, that in the past greater care has been exercised in the manufacture of iron than is now given to the manufacture of steel.

For bridge construction, the railroads that can afford it are going back again to stone construction, and, indeed, some of them are very seriously considering the use of wood for bridges. There is still in use, on a portion of the Pennsylvania Railroad system, one old wooden bridge, which has been standing for a great many years.

Mr. Joseph T. Richards.—In the examination which was made of the old Viaduct bridge after its destruction, it was found that one end had its foundations on the solid rock, while the other rested on timbers. The débris carried by the water dammed up to a height of about ninety feet, and then the flood scoured out under the latter foundation, probably, and it went first.

I will try at a future meeting to give you some more definite facts regarding the results of this examination.

[The cut in this article of the Old Conemaugh Viaduct was lent by Mr. Barkesdale of the Advertising Department of the Pennsylvania Railroad.—Pub. Com.]

VIII.

THE NEW BUILDING LAW OF THE CITY OF PHILADELPHIA.

By Frederick H. Lewis, Active Member of the Club.

Read, March 17, 1894.

By the signature of the Governor of the Commonwealth on June 8th of last year, a general building law was enacted for cities of the first class in Pennsylvania, and by ordinance of City Councils, the Bureau of Building Inspection is now about to be reorganized and enlarged in order to give this law full effect and force in the City of Philadelphia.

Yet the writer risks very little in expressing the opinion that those who may have to deal with this law will inevitably find it seriously defective, not only in matter, but also in its own coherence.

Building laws are not especially novel. This City has had state laws and city ordinances ever since 1855 and until now its building has been governed chiefly by laws passed prior to 1870. In a majority of the larger cities, such laws are in force, and while nearly all of them leave something to be desired, the net result probably serves the public interest to a considerable degree.

Of recent general laws enacted prior to our own, those of the cities of New York and Boston enacted respectively on 9th of April and the 16th of June, 1892, are the most notable. These laws are especially interesting in this connection because they have been drawn upon very freely by the authors of the law we are now considering. This is shown chiefly by the reproduction of clauses, sentences, and sometimes whole sections, and is so clear there can be no doubt of it.

Now it is to no one's discredit to seek to profit by the previous work of other people, but we judge men by the use they make of resources. In the present case it is remarkable that such poor results could have been achieved from an abundance of fairly good material.

Because of this connection, the writer will make frequent reference to the New York and Boston laws in illustrating matters criticised. For, whatever the defects of these laws may be, their English is generally clear and well defined, and, as a rule, the regulations are technically correct and of general application.

These things cannot be said of the Pennsylvania law. It is neither clear nor forceful, and its regulations for the most part give details which are not of general application. Perhaps "purposeless" is the word which best describes it. There are pages of matter well enough in its way, but which entirely fails to reveal the purposes in view or to adequately carry them out.

In an Engineers' Club, the discussion is, of course, primarily from an engineer's standpoint, but as a local issue the administrative features of this law are interesting and will be considered first.

The law is practically an extension of the Bullitt Charter and constitutes a Bureau of Building Inspection under the Department of Public Safety.

It is sufficiently clear from Sections 4 and 5 that no building can be hereafter erected or altered, and no work affecting the strength or fire risk of any building can be done except by permit from the Bureau, and that the Bureau can grant permits only after examination and approval of the plans and specifications. Besides the text of the law, the Bureau is authorized to use its discretion in several important matters. The chief of these are:

1. To decide the thickness of pilasters and spandrel walls for buildings in which the weight is carried wholly by an iron or steel framework.

2. To order the tearing down or repair of existing party or division walls if not deemed satisfactory for new constructions or alterations.

3. To require piers and buttresses to be heavier than specified.

4. To decide for or against proposed roof and cellar floor coverings.

Then, as the law gives no rules for walls over six stories in height, and deals little with the new building problems now inter-

esting engineers, the Bureau must consider all these things at discretion, and as wisely as it may, in passing upon plans and specifications. Because, as regards plans and permits, the powers of the Bureau are great, almost arbitrary.

It is certainly very desirable that a Bureau exercising such a censorship as this over the building designs of the City should be well equipped in technical information, experience and ability. The law, unfortunately, gives little encouragement in this direction. It provides, without making any distinction whatever, that the chief and assistant inspectors shall be either practical builders, civil engineers, carpenters or bricklayers. Architects have no standing at all; and it can hardly be expected that engineers will seek positions which place them exactly on a par with carpenters and bricklayers. This regulation is a bar to good men, and is unnecessary.

The Boston law makes much better arrangements. The chief must be either an engineer, an architect or a builder, and his force is divided into engineers, clerks and inspectors with distinctive duties. The New York law is better yet and goes straight to the mark without any nonsense. The Superintendent is appointed by the Mayor and he may engage and fix the compensation of "such officers and employees" as shall be necessary in executing the duties imposed by the law.

There are certain appeals, within specified time limits, from the decisions of the Bureau on permits, and from the discretionary decisions mentioned above; first to the corps of inspectors sitting as a Board, and afterwards to a Commission of Experts. These appeals are open to adjacent property holders affected by new constructions.

The powers of the Bureau in granting permits is ample; but once a permit is granted the question arises as to what authority Building Inspectors can exercise on work in progress. Can they pass upon the quality of the materials? Can they condemn bad work or require it to be taken down and rebuilt? Are architects, builders, or mechanics subject to inspectors' orders or answerable for neglecting them?

These are very pertinent questions, but the law fails to answer them. It has just two things to say, as follows:

1. "Inspectors shall examine all buildings in course of erection or alteration, and make a record of all violations of the Act."

2. "Inspectors may require columns to be drilled for inspection."

There is nothing further either in the general text or in the details which would warrant us in thinking they had any other functions.

There are no fines or penalties except a general process and fine in Court to enforce decisions which appear to be limited to the following:

1. On permits.
2. On unsafe walls.
3. On underpinning between adjacent properties.

On work in progress it is not clear that inspectors can decide anything or do anything beyond making a record of violations in a book; and if they have other powers it will probably require a decision of Court to establish them.

It is remarkable that the law should be obscure in this respect, and it may be troublesome. It is especially remarkable because the Boston and New York laws, which were copied in solid paragraphs in the administrative regulations, are quite clear and explicit. Boston inspectors pass upon all materials, may modify foundations, and are given large powers to require work to be not only properly constructed, but carried forward with special regard to public safety.

New York inspectors may pass upon any question of manner of construction, or material used, and owners, architects, builders, and mechanics may be fined for failure to build in accordance with plans and permits, or for failure to comply with orders made under the law. The older laws of this city are not defective in the way the new one is.

We come now to that phrase in Section 26 which reads: "In all warehouses, storehouses, factories, workshops and stores . . . ., the weight which each floor will safely sustain . . . ., shall be estimated by an engineer or architect, with the date thereof, and posted by the owner in a conspicuous place . . . ., within one year from the date of the passage of this Act."

This refers to existing buildings, and the regulation, properly

enforced, would serve the public interest in a very high degree. It is important to know that buildings are not overloaded and dangerous, and it is desirable to remove entirely those which through age and decay are unfit for further use. And if the surveys were thorough and accurate, and the Bureau had full authority to act upon them, this desirable result could be achieved.

But the phrase quoted above is everything this law has to say about the matter. There is no precaution to insure that these surveys shall be reliable, and the Bureau is not authorized to take any action upon the results, nor does it even get copies of the reports.

Now, this regulation, as far as it goes, is taken from the New York law, but the latter does not stop with a phrase, but continues as follows: "Such estimates shall be reduced to writing, stating the material, size, distance apart, and span of beams and girders, posts or columns to support floors, and its correctness shall be sworn to by the person making the same, and it shall thereupon be filed in the office of the Bureau . . . . But if the Superintendent of Buildings shall have cause to doubt the correctness of said estimate, he is empowered to revise the same, and for the purposes of such revision, the officers and employees of said Department of Buildings may enter any building and remove so much of any floor or other portion thereof as may be required to make necessary measurements and examinations." "The weight placed on any of the floors of any building shall be safely distributed thereon, and the Superintendent of Buildings may require the owner or occupant to redistribute the load on any floor or to lighten such load, as he may direct." This is as it should be, but why was it omitted in our statute?

Turning to the details of construction given in the law we find, beginning with Number 7, some half dozen sections relating to enclosing walls, foundations and footings. The matter has been culled from various sources, and is a confusing mass of special details of no particular value, and which are apt to mislead in many cases. There is scarcely an intimation that walls should be proportioned to carry loads, or that foundations are intended to distribute the loads upon the earth with pressures suitable to

the bearing capacity of the soil. The tables of safe bearing pressures on different classes of masonry and on different foundations which are usually found in building laws are omitted. It may be said, perhaps, that the sizes of the footings given are minimum sizes, and that proper footings for particular cases can be reckoned from the text-books. So they can; but in many cases they will not be; and the requirements of the law will fix the dimensions, and will be misleading.

It will hardly be claimed that the details specified are well considered when they are found to be out of proportion to the walls and floor loads called for. Almost any of the six-story walls given in Sections 11 and 14 will load the specified footings over 7,000 pounds per square foot by their own weight alone, or from 12,000 to 20,000 pounds per square foot, including floor loads; and even a three-story party wall with its floor loads will put 10,000 to 12,000 pounds bearing pressure on these footings.

What is the use, too, of specifying that the lower footing course under columns must be not "less than nine square feet greater in area than the size of the column," when the footing will be overloaded by the specified floor loads in any building over two stories in height. A single sentence fixing the allowed bearing pressures on foundations would be very much better than all the statute has to say on the subject.

The practical requirements of the statute may be summed up thus: Foundations must be three feet below ground and one foot below cellar bottoms, and foundations and cellar walls must be laid in cement; then be sure to calculate your footing areas in all cases.

In the tables of enclosing and division walls of business buildings, we find that the idea of making walls heavier in proportion to their length has been elaborated. No regular rule has been followed in doing this; sometimes it is the first story, sometimes the second or third, sometimes the first and fourth and sometimes the greater part of the wall. The greatest increases are from walls 150 feet long to walls exceeding 150 feet. The greater part of entire walls are increased four inches for this increase in length, and at the end of the tables we read that for each fifty feet additional length over 150 feet, the thickness must

be increased four inches; presumably for the entire wall. This idea of increasing the thickness of walls because of their length has not had very wide recognition, and the writer would prefer to leave the discussion of it to the meeting, merely raising the question whether, after passing some limit, length is not itself an element of stability.

It will be noted that no modification is made because of cross walls or bracing. The New York law says: buildings that are over 105 feet long without a cross wall or proper piers or buttresses, shall have the side walls increased four inches for every 105 feet, or part thereof, increase in length; and on the other hand provides for reducing the thickness of walls in certain cases if there are cross walls, piers or buttresses. This seems a more reasonable regulation.

The paragraph immediately following the tables of walls (Section 11) is most confusing. As Mark Twain says, it makes you dizzy. It proves, on careful examination, to be an amusing instance of the kind of literature which may be achieved by the aid of a pair of shears. It reads thus: "Where trusses are used the walls upon which they rest shall be at least four inches thicker than is otherwise required by this section; for every addition of twenty-five feet, or part thereof, to the length of the truss over thirty feet, the amount of the materials specified may be used either in piers or buttresses, in outside, and division or party walls." The fact is, the first part of that sentence comes from Boston and the second part comes from New York. There is a semicolon in the wrong place and the period has been unfortunately omitted, so that here we go from Boston to New York without a stop. The sentence should read as follows: "Where trusses are used, the walls upon which they rest shall be made at least four inches thicker than is otherwise required by this section, for every addition of twenty-five feet, or part thereof, to the length of the trusses over thirty feet. The same amount of materials specified may be used in piers or buttresses." It looks odd and is confusing to see the thirty feet truss length of the Boston law appear in this way, when we have read just above that thirty-four feet is the limit for our statute.

It might be interesting to discuss whether, from Section 11, the

Chief of Bureau may increase the thickness of any wall or only of piers and buttresses, and also to ask what Section 12 means; but time forbids.

The enclosures of fire escapes, stairways, elevator shafts and light wells are expressly relieved from regulations, and the law does not deal with fire-proof building construction at all.

The safe loads of floors for all classes of business buildings, new or old, are required to be estimated by an architect or civil engineer. The loading on the floors of new buildings, exclusive of materials, is to be reckoned as follows:

For dwellings	70 lbs. per sq. ft.
If used for public assembly	150 lbs. " "
For storehouses, warehouses and manufactories	200 lbs. or more per sq. ft.

The calculations for beams and girders are to consider them as loaded at the center "in all cases." The unit strain for beams and girders is to be one-fourth of the ultimate strength; and for posts, columns and tie rods one-sixth; and the computations are required to be made by those rules of standard authors in which the "constants have been deduced from actual experiments."

Now a beam or girder will, of course, carry at its center one-half the load it will carry uniformly distributed along its length. But the assumption, for all ordinary building constructions, is that floor loads are uniformly distributed, and there is no reason whatever why concentrated loadings should be considered in dwellings, office buildings, public halls, or in the great majority of stores and factories. Hence the present law requiring the beams to be considered as loaded at the center "in all cases" may be reduced to ordinary practice by stating the loads to be as follows:

For dwellings	140 lbs. per sq. ft.
If used for public assembly	300 " " "
For warehouses, storehouses and manufactories	400 lbs. or more per sq. ft.

It is to be noted that in Section 17, girders (that is, beams carrying joists or other beams) must be reckoned for at least 200 pounds in buildings of any class. Such loadings are unprecedented and unwarranted by considerations of fact. The weight of a densely-packed crowd of people does not exceed 80 pounds per square foot, and 100 pounds per square foot is considered

quite sufficient for office buildings, for ordinary halls and for highway bridges. For dwellings 50 pounds is sufficient and 70 pounds ample, and for floors carrying machinery from 200 pounds to 400 pounds per square foot is a proper allowance. A comparison of the Chicago, New York, Boston and Philadelphia laws for distributed loads in pounds per square foot will be as follows:

	Chicago.	New York.	Boston.	Philadelphia.
Dwelling, tenement, apartment house or hotel	70	70	70	140
Office buildings	70	100	100	——
Public assembly	——	120	150	300
Stores, factories, manufactories, etc	150 or more.	150 or more.	250	400 or more.

It will be noted here that our classification is not complete; office buildings and hotels are omitted, and stores also, perhaps.

It is therefore now a fact that under the law of the Commonwealth we must build our house floors heavier than is necessary for theaters; the floors of our halls and churches adequate to carry heavy machinery, and warehouse floors like railroad bridges.

The amount of material required might not be excessive if the unit strains were high, but they are not. For beams and girders, unit strains are one-fourth the ultimate strength—the usual practice. Of course the concentrated load business does not increase the load on columns, because the loads on them are always concentrated. But the law forestalls this by putting the unit strains at one-sixth the ultimate strength, or from 50 per cent. to 65 per cent. of the figures usually adopted for wrought iron or steel in buildings. So that the iron work on Philadelphia buildings must be just about twice as heavy all round as in usual practice elsewhere.

What the law means will be understood when it is stated that *hemlock* and spruce joist *spaced* 12 *inches between centers* are only good under the law for spans as follows:

	In dwellings.	In public halls.	In manufactories.
8 × 2 joist,	7 feet.	5 feet.	4 feet or less.
12 × 2 "	11 "	7¾ "	6¼ " "
12 × 3 "	13½ "	9½ "	7¾ " "
14 × 3 "	15¾ "	11 "	9 " "

It might not be improper to call the new law " a law to prohibit the use of wooden joist in buildings." That the authors of the law did not realize what they were doing is evident from Section 34. We read there, that in dwellings of " 16 feet front or less " the joist for first floor shall not be less than 9 $\times$ 3 spaced 18 inches centers, and for upper floors not less than 8 $\times$ 3 spaced 16 inches centers. Hemlock joists of these sizes are good for just about half the span stated.

It will be remarked that this matter of floor loads is the only instance in the law in which the authors have ventured to give technical rules, and it is probably a matter for congratulation that they did not attempt any more.

The law says very clearly in Section 26 that for beams and girders, the unit stresses shall be one-fourth, and for columns, posts and tension rods one-sixth of the breaking strength respectively, and that the dimensions of parts are to be computed by those rules of standard authors in which the constants have been reduced from actual experiments. This is explicit; but it is presently confused by a clause which we find in Section 24 which reads thus: " And no greater weight shall be placed on any column, post, beam, lintel, or girder than the published tables of said manufacturer or founder show it to be capable of sustaining with safety." Of course this is absurd, because any manufacturer can readily get up tables to show that his products will " sustain with safety " not one-fourth or one-sixth of their breaking strength, but a third or even half, and still be able to argue his position.

In connection with the live loads of buildings, the writer raises the question whether a general rule for estimating live loads on columns and on foundations is not desirable and practicable. Beams and girders must, of course, be proportioned for the full specified live loads, but the lower story posts can only get the full live loads when all the floor panels above are fully loaded. The proportion of live load which they are ever likely to carry decreases therefore as the number of stories above them increases. Probably in a ten-story building 60 per cent. of the assumed live load would be an ample estimate for the basement columns or footings.

The latter part of the law about hearths, chimneys and registers, and Section 40 about theaters, is very well, especially the theater regulations. The text is taken from the New York law.

The writer has endeavored to set forth here the defects of the Philadelphia Building law as he has noticed them in reading it. Without doubt many other contradictions and obscurities will be found and many cases in which it is quite inadequate.

It is remarkable how much is omitted which is found in other laws, and which one expects to find in a modern building law. This is negative. But it is positively bad to such an extent that the building operations of this city should not be saddled with it, and that its early revision must be insisted upon.

DISCUSSION.

Mr. Amory Coffin (*visitor*).—I feel privileged to be at this meeting of the Club, and have been much interested in this subject and its presentation. When the crude draft of the Law passed first reading in our Legislature, a friend sent me a copy of it, and after looking over it carefully, I sent it with some suggestions as to how I thought it might be improved, to our representative, calling his attention to the way similar points had been treated in the New York Law, and although my suggestions were probably considered, none of them were embodied in the Law as it was adopted. In its present form considerable embarrassment has already occurred by its application. For instance, in two sections the provisions for floor loading are stated, and as they are not alike, it is difficult to know which of them should be applied. In one case that I know of, the provision for center loading was construed to mean that all the loads specified should be doubled before calculating the proper size of the beam, according to our usual rules.

Mr. W. W. Stevens.—I have no doubt that if you take into account the number of people who took part in the framing of that Law, you will be surprised that it is not worse than Mr. Lewis seems to consider it. It was debated upon and amended by committees from our City Councils, Master Builders' Exchange, Architects, and, indeed, almost all of the Building Societies, and the Press and the Public at large had their say in the matter.

Though the Law may be defective in many points, it has accomplished one good purpose at least, for the attention drawn to it by its use and enforcement will, perhaps, result in the production of one which can meet with the approbation of Mr. Lewis and some other members of this Club. It was not intended, of course, to apply to such structures as the Bourse, the Drexel or Betz Buildings, but there are many houses in this city, workingmen's homes, and even factories, for which the plans are drawn by builders, whose chief effort is to make the construction as cheap as possible, even at the sacrifice of necessary safety. I am sure that if Mr. Lewis had had a hand in the framing of this Law, it would have been all that he at least could have desired, and I trust that should it come up for amendment, we may have the advantage of his valuable assistance.

Prof. Lewis M. Haupt (*visitor*).—The Building Law, although designed for an excellent purpose, is a very verbose one, being full of details, some of which are ambiguous. Section 26 is not explicit as to dwellings, theaters, churches, schools and places of public assembly, which are sometimes greatly everloaded, and although it specifies the safe unit load for dwellings it is merely incidental.

Our inspections, which have included a large range of buildings, have shown the necessity for the measure, as we have frequently found the safe load of a floor reduced by placing a number of joists upon a beam or girder of lesser strength. By attention to the proper distribution of material, the floor strength may be increased in some instances over one hundred per cent.

It would seem to me that in any revision or amendment of the Law, it would be well to leave the details, as to material and construction, in the hands of the Bureau of Building Inspection to make their own regulations, and to make provision for the inspection of the strengths (as distinct from construction details) by any qualified engineers.

It would also be well to provide that in examinations of buildings, the occupants should be advised as to the best disposition of the load, as well as of the amount that their floors will sustain.

Mr. James Christie.—An eminent English writer has pointed

out that almost any wording, if too carefully criticised, can be given various interpretations, and while I agree in the main with Mr. Lewis' remarks, I think that the above may apply to some of his criticisms.

In matters of building inspection the most important consideration is the character of the inspectors, and if they are competent men, I think that the law which we have, even though it may be defective in some respects, will be able to accomplish a great deal for Philadelphia buildings.

Mr. Stacy Reeves (*visitor*).—I would like to ask why, when the Philadelphia Chapter of Architects was notified to send a Committee to consider the draft of this Law, they did not send representatives who were engineers as well as architects.

Prof. Haupt.—I do not know that this is an answer to Mr. Reeves' question, but there certainly is a feeling among Architects that they are responsible only for the artistic design of a building, it being the duty of another party, namely, the engineer, to provide for the strength of the construction.

Mr. Stevens.—The original drafts of the Law contained many other provisions which were considered important, but which we were obliged to omit in deference to conflicting interests.

Mr. W. C. Haddock (*visitor*).—The original Section 24 was cut out and another substituted at the instance of a representative from Phœnixville, whom we understood was speaking in the interest of the Phœnix Iron Company.

Mr. Coffin.—That was a great mistake, as we had nothing whatever to do with the framing of the Law.

Mr. W. C. Furber.—The Inspectors should, I think, be engineers of some experience, or the powers of the Inspectors should be limited and defined, as it is impossible for an Inspector to be able to decide quickly a point at issue, unless he is familiar with the theory of the design of the building, which knowledge is hardly to be expected from a man unacquainted with the methods of scientific reasoning.

It is my opinion that the building law of any city should be confined to prohibiting abuses which should be enumerated, and to the authorization of permissible "unit strains" in the use of all building material. It might be modeled somewhat on the order of Theodore Cooper's specifications for bridges, which has been

found sufficiently elastic to adapt itself to most cases and at the same time to prohibit bad or faulty practice.

Many things in the new Law have been entirely overlooked, such for instance as the loading of party walls. The Law is stated in terms of height and thickness, rather than in terms of strength. There is nothing to prevent party walls from being subsequently overloaded by the adjacent builder, who is required to examine the wall for thickness and condition, no examination being required of the footings to ascertain their distributing capacity. No allowance is made for the superior resistance of brick walls laid in cement, the law reading "lime or cement mortar," no proportions being given for either.

The live loads required by the law (overlooking the "applied at the center" clause as manifestly absurd), are, I think, too great. Floors of ball-rooms should be strong enough to take care of the impact of the moving load and vibratory effect, but office buildings and ordinary rooms of hotels and dwellings should not be required to carry either 70 or 150 pounds per square foot. Mr. Blackwell recently obtained some data in Boston, regarding the weights in office buildings, and after weighing furniture, carpets and their ordinary maximum total load, found that the loads were from five to forty pounds, with an average, I think, of about seventeen pounds. A floor should be heavy enough to sustain any reasonable load that could be brought upon it, but a building should be used for the purpose for which it is designed and the floors and columns should be proportioned accordingly.

Regarding columns and the factor of six required, the manufactured column of mild steel is good for about 33,000 to 39,000 pounds, depending somewhat upon its section. I do not think yielding strength will run above this, while the unit strains ordinarily used, of 12,000 and 13,000 pounds, allow a factor of three and less. The yielding point in a beam is the elastic limit, and its ultimate working load, used at the ordinary stress of 16,000 with an elastic limit of say 30,000 and above, gives a real factor of only two or less. If beams are safe at two, the column which has the advantage in probably not receiving its full load, will require only three.

No reference whatever is made to eccentric loads on columns,

and in building construction nothing is more common. An exterior or curtain wall column is necessarily eccentrically loaded and provision should always be made for the bending so induced, by increasing its moment of inertia.

I think it advisable in high buildings to permit the total amount of live load supposed to be carried by the lower columns to be reduced somewhat on the reasonable assumption that the total maximum live load will never be realized at one time. The basement columns in the Fair Buildings, Chicago, are figured for only forty per cent. of the total live load above them. It is quite customary to figure girders of any considerable span for a percentage of the load on the joists, generally about eighty-five per cent., and for columns seventy-five per cent. live loads.

The law should also, I think, say something about wind bracing of high buildings. With a high narrow building the lack of such bracing is a serious omission. Certified tests of the steel used in the construction of buildings of any size should be filed with the Bureau, as there is possibly a greater chance of poor material being used here than in any other department of the work, its defects being less apparent. All steel work should also be required to be painted thoroughly with good oil and red lead. Patent paints of any kind should not be permitted, as corrosion of the skeleton work of a metal building might occasion serious calamities.

The fire escape clause is not sufficient. Most of the fire escapes constructed in this city would fall before an ordinary load could come upon them. Those which are, in the words of many architects' specifications, "satisfactory to Bureau of Fire Escapes," would not, probably, be so satisfactory to the occupants in case of fire.

Mr. Amos W. Barnes.—I have noticed that the limit of deflection allowable in beams is not specified, and our floors in consequence are being more poorly built than in most other cities.

Mr. C. Henry Roney.—In reply to Mr. Barnes, the time is too short this evening to answer his question in reference to deflections of various floors in detail, while the general features of the Building Law are under discussion; but as Mr. Coffin has referred to my first having called his attention to the proposed Building Law, I may say that having heard that such a law had been in-

troduced in the Legislature, and securing a copy from a Senator, I brought it to the attention of Mr. Roberts of the Pencoyd, and of Mr. Reeves and Mr. Coffin, of the Phœnix Iron Company. The latter two gentlemen and myself went over the bill carefully and suggested certain amendments to some members of the Legislature, but they were not acted on, so I can corroborate Mr. Coffin's statement that he was innocent of the charge of having had changes made in the bill. Some of my criticisms appeared in one of the daily papers at the time without effect, and it became evident that the only way to do was to let the public learn the defects of the law from experience, and to endeavor to have it amended at the next session of the Legislature.

In reference to the deflection of floors beyond which the plastering may crack, to which Mr. Barnes has alluded, I may as well say briefly that I have understood that the original rule that the span of a floor beam should not exceed a certain proportion of its depth, was based on some experiments on wooden joists and floors, beyond which their deflection was thought likely to crack the ceiling plastering. These proportions may admit of some modification in floors composed of iron beams and brick segmental or flat terra-cotta arches or lintels, where the rigidity and spacing of the beams and arches and proportion of live to dead load are quite different from those in the former case. It is self-evident that as the beams and arches have deflected to a certain extent from their own weight before they are plastered underneath, any further deflection which might tend to crack the plastering, can only be caused by the live load afterwards added, so that the dead (permanent) load has no influence in cracking the ceilings.

Prof. Edgar Marburg.—To accomplish something definite from the paper and discussion which we have listened to, I would like to suggest that a committee be appointed to take such action as would lead to an amendment of this law in some of its more important and defective points.

(The President explained that such action could only be taken at a business meeting, for which it had been announced.)

Mr. Roney.—The Legislature will not meet again until the early part of next year, which should give ample time to draw up satisfactory amendments to the Law.

JOSEPH D. POTTS.

Sixty-four years, lacking one day, was the span of life allotted to this member of the Engineers' Club, who was intrusted with the care of many important interests, and whose busy life was scarcely suspected by those who met him socially.

Joseph D. Potts was born at Springton Forge, Chester County, Pa., December 4, 1829, and died at Milton, Pa., December 3, 1893.

His early years were passed in the neigborhood of his birthplace, where several generations of his family have conducted the iron industry, and he was so partial to this branch of trade that he reconstructed the Isabella furnace, and became interested in rolling mills and tube works at Pottstown and Chester.

He began his career as a civil engineer upon the staff of the Sunbury and Erie Railroad, where his executive ability and his methodical life brought him success as a railroad man, and gave him an opportunity to associate with those who were engaged in transportation. These interests became more absorbing as his years matured, and were the means by which he acquired a large part of his handsome fortune.

At the outbreak of the War of the Rebellion, Governor Andrew G. Curtin, needing a man of marked ability and high character as chief of the transportation and telegraphic department of the State of Pennsylvania, appointed Mr. Potts, giving him the rank of Colonel.

This position he filled to the entire satisfaction of all officials during a most chaotic period, before the United States Government had the opportunity to assign a regular officer for the place. A year later, because of the efficient management of this work, General Reynolds appointed him Military Superintendent of Railroads. His early training had made him so familiar with the duties of this position, that his service was of advantage to the Government and credit to himself.

After the war, in which he took an honorable part, he was

elected President, Vice-President, Manager and Director of numerous railroads, transit, storage, dock and steamship companies, to the great advantage of the corporations. Nor did he allow his diversified business to occupy all of his valuable time, but gave part of it to the service of the public, becoming one of the Trustees of the University of Pennsylvania and one of the Board of Prison Inspectors, as well as participating actively in several charitable organizations.

Many have reason to remember him for substantial aid given without ostentation, and it may be truly said that "his good works follow him."

A character so mild and gentle, yet so firm and noble, could not exist without being, perhaps unconsciously, a bright example to his fellow-workers.

Mr. Potts joined us in 1888, and we thought it an honor to have him numbered with us. We are proud to believe that the great interest which he manifested in the welfare of the Club was prompted by the fact that he began his business life as a civil engineer. Those of us who have enjoyed the generous hospitality of his home, can add another tribute to the social attributes of an exemplary life.

It is with feelings of regret that we note the end of a career so useful, so prosperous, so honorable and so full of every manly virtue.

A memorandum of some of the prominent positions held by Colonel Joseph D. Potts is as follows:

Vice-President of the Steubenville and Indiana Railroad; Superintendent of the Western Division of the Pennsylvania Railroad; President of the Western Transportation Company; General Manager of the Philadelphia and Erie Railroad; President of the Empire Transportation Company and of the Erie and Western Transportation Company; Managing Director of the National Storage Company and President of the National Docks Railroad Company, both of New Jersey; President of the Enterprise Transit Company; President of the Girard Point Storage Company; also, one of the Directors of the Inman and International Steamship Companies.

NOTES AND COMMUNICATIONS.

A HYDRAULIC PROBLEM.

At the meeting of February 17th, Mr. John C. Trautwine, Jr., contributed the following:

Mr. H. K. Nichols, Chief Engineer of the Philadelphia and Reading Railroad, recently called my attention to a simple device, by which he regulated the flow through two pipes having very different heads.

From the Mud Run Reservoir in Schuylkill County a 10-inch pipe leads, for a distance of 8,000 feet, to the village of Frackville, in which are certain locomotive plugs and fire plugs. In this distance the fall in the pipe itself is 40 feet, while the head within the reservoir above the inlet to the pipe is 20 feet. There are in this portion of the line two curves amounting together to about 90 degrees.

At Frackville the 10-inch pipe branches out into two pipes of 6 inches diameter, the short one running to the head house of the Mahanoy Plain and a much longer one leading down to the village of Mahanoy Plain, where it connects with a longer 6-inch pipe running eastward to Gilberton, and with a 4-inch pipe running further eastwardly to Bear Ridge West. The 6-inch pipe running from Frackville to the head of the plain is about 1,500 feet long. In the first thousand feet of its length it rises about 2 feet and then falls about 10 feet to the upper story of the head house, after which it falls some 15 feet to the cellar of that building.

The longer pipe, starting out from the dividing point and running first to the village of Mahanoy Plain, has a length of 3,200 feet and a fall of 340 feet. The pipes to Gilberton and to Bear Ridge West, with which it connects at the town of Mahanoy Plain, are practically horizontal.

The difficulty experienced was that owing to the much greater head in the long pipe, the valley at the end of the long pipe got all the water when engines were watering, leaving practically none for the head house at the top of the plain, at the end of the shorter pipe.

The natural remedy was a stop valve in the long pipe just below the branch, but it was felt that no dependence could be placed upon the watchfulness of those in charge of such an apparatus, and after considerable study Mr. Nichols hit upon the simple expedient of introducing in the long pipe just below the branch, a siphon about 18½ feet high. This siphon was thereupon introduced and the trouble was at once remedied, and has remained so during the subsequent period of a dozen years.

To prevent freezing, the siphon was enclosed in a timber house, and the two floors of that structure have been utilized for storage, etc., while a tap in the side of the siphon gives water for such purposes as may be needed in the building. During recent years the upper floor has served as a lever-house for signaling apparatus.

It seems difficult to explain just why this device should have remedied the difficulty, unless we bear in mind the imperfection to which all siphons are exposed, namely, that of gathering air at the summit, which air, forming a cushion, retards

the flow. It must therefore, I think, have been the imperfection of the siphon as such, that enabled it to act in retarding the flow.

The siphon is provided with a blow-off cock at the top by which the air is allowed to escape when it accumulates in too great quantities.

SOME RESULTS OBTAINED IN THE GOVERNMENT INVESTIGATIONS OF AMERICAN TIMBERS.

Contributed by E. R. Kellar, Active Member of the Club, at Meeting of March 17, 1894.—The timber investigations now in progress under the supervision of Mr. B. E. Fernow, of the Forestry Division, by whom the work was also planned, was first brought to the attention of the Club by Mr. Fernow himself in a most interesting lecture delivered before the Club in October, 1891.

Mr. Fernow pointed out that it was the object of these investigations to determine the physical, mechanical, chemical and other properties of our American timbers, and especially the interrelation existing between these various properties. He proposed to combine the results and establish the science of "Timber Physics," which, so far as American timbers are concerned, is quite new, and, indeed, the subject of timbers has never before been treated in so comprehensive a manner in any country.

Since that time the investigations have been productive of some valuable results regarding the "Long-leaf Yellow Pine," so abundant, especially in the Southern States. I have condensed such parts of the work* for this paper as are of a special interest to the engineer.

It may be of interest, first, to describe briefly some of the methods and apparatus used. In the main these are the same as those used in determining the properties of metals, some difference being necessitated by the properties peculiar to timber. The mechanical tests are all carried out under the supervision of Prof. J. B. Johnson at the St. Louis Test Laboratory.

The logs, which vary from 12 to 18 feet in length, reach the laboratory in pieces sawed and stenciled in such a way that their exact location on the tree can be traced by means of the tree chart. Some of the sticks are tested at once, while others are subjected to various periods of natural or artificial seasoning.

The mechanical tests include:

(*a*) cross breaking of large and small beams.
(*b*) tension.
(*c*) compression—endwise and across grain.
(*d*) shearing.
(*e*) tests on full-sized columns.

The machines used for making these tests are fully illustrated and described in Bulletins 6 and 8, to which reference has already been made.

Two machines are used for making the cross-breaking tests—one of 100,000 pounds capacity for testing large beams, and a smaller machine for testing small beams (4″ × 4″ × 6′ — 0″.)

(*a*) The results of the cross-breaking tests were plotted in a curve, using the deflections as abscissas and the loads as ordinates. From the curve the modulus of elasticity was taken, as

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* "Timber Physics," Parts I and II, Bulletins 6 and 8 of the Forestry Division, Department of Agriculture.

$$E = \frac{W}{D} \cdot \frac{l^3}{4\,b\,h^3}$$

Where

$W =$ load in pounds.
$D =$ deflection in inches.
$l =$ length " "
$b =$ breadth " "
$h =$ height " "

the value $\frac{W}{D}$ being taken as the tangent of the angle made by the original direction of the curve with the axis of abscissas. The modulus of rupture is calculated from

$$f = \frac{3\,W\,l}{2\,b\,h^2}$$

In metals the work done on the specimen up to the elastic limit—called the elastic resilience—is usually taken as a measure of its toughness, but since there is no marked elastic limit in timbers an arbitrary point must be assumed. It is taken as that point of the curve at which the rate of deflection is 50 per cent. greater than it was at first. The work done up to this point, divided by the volume of the beam, is taken as the modulus of elastic resilience. It is a measure of the toughness and is independent of the dimensions of the beam, for:

$$D = \frac{W\,l^3}{4\,E\,b\,h^3}$$

$$W = \frac{2\,b\,h^2}{3\,l\,f}$$

$$W\,D = \frac{2\,b\,h^2}{3\,l\,f} \times \frac{2\,b\,h^2}{3\,l\,f} \times \frac{l^3}{4\,E\,b\,h^3} = \frac{b\,h\,l}{9\,E\,f^2}$$

and dividing this by the volume $b\ h\ l$ we find that the expression becomes

$$\frac{W\,D}{V} = \frac{l}{9\,E\,f^2}$$

which is independent of the dimensions of the beam.

(*b*) The tensile tests are made in a universal machine. The sticks are cut from the end of beams which have failed and pared down at the center, the breaking section being $2\frac{1}{2}'' \times \frac{3}{8}''$.

(*c*) The endwise compression tests are made on specimens 4″ square and 8″ long, on the same machine, failure usually occurring over a plane section by crushing or shearing.

In crushing across grain an arbitrary limit of 3 per cent. of the height is taken as the maximum deformation, the stress at that point being called the ultimate compressive strength across grain.

(*d*) For the shearing tests, specimens 2″ square and 8″ long have rectangular holes mortised 1″ from the ends, the holes being at right angles to each other. The specimen is held by means of stirrups, and when one end is sheared out an auxiliary stirrup and pin hold the specimen at the center so that the other end may be pulled out, giving two sheared surfaces at right angles to each other. Clamps prevent the sides from being forced out during the tests and are screwed down very lightly.

(*e*) The machine for testing full size columns has a capacity of 1,000,000 pounds, and will take a column 14″ square and 30′ long. In addition to those already mentioned, tests for specific gravity and percentage moisture are made, so that the influence of all the properties on each other may be determined.

Of the upwards of ten species of pine which are found in the Southern Atlantic and Gulf States, not more than four reach our Northern markets, and of these the long-leaf yellow pine has no less than twenty-three different names, arising partly out of the practice of designating different qualities by different names, and partly from an indiscriminate use of local names. It is, therefore, not strange that considerable confusion exists in regard to these four different species, which have an aggregate of sixty different names. The long-leaf species may be distinguished from the others in several ways, principally by its long leaves (9 to 12 inches), of which there are always three in a bundle, and long cones, 6 to 9 inches in length. Its wood is the heaviest of the Southern pines, weighing, kiln-dried, about 48 pounds per cubic foot. It has a fine and even grain, reddish-yellow color, very little sap wood (rarely over 2 or 3 inches of the radius), and is pitchy throughout.

In regard to its geographical distribution; it is found in the best drained, deep, sandy soils, and is very plentiful in many of the Southern States, especially in Georgia, Alabama, Louisiana and Texas.

The results given in the following tables are derived from tests on 2,150 specimens, cut from twenty-six trees, all from Alabama. The test-specimens included pieces in all stages of seasoning, from green to perfectly dry. Sixteen of the trees had been tapped for turpentine, eight of which had been abandoned for five years and eight recently tapped.

Table I gives the values of all the quantities pertaining to the strength, stiffness and toughness of the material, reduced to 15 per cent. moisture. It was shown, among other things, that, with the exception of the modulus of elasticity and tensile strength, all of the other properties were improved by tapping for turpentine.

Table II shows the relative properties of large and small beams cut from the same tree; here, too, the results are reduced to a basis of 15 per cent. moisture, which is the usual amount contained in seasoned lumber under shelter but out of doors. The table shows that, while the modulus of rupture is slightly greater in the small beams, the strength at the elastic limit, as well as the modulus of elasticity, are considerably higher in the large ones.

In regard to the variation of the individual tests from the average, it was found that this was least in the case of compressive (endwise) tests, the results of over one-third of the pieces being within 5 per cent. of the average. The variation was greatest in the tensile tests. If only one test can be made, it should, therefore, be compressive. It was shown, also, that all of the properties, with the exception of tensile strength and specific gravity, decrease as the percentage of moisture increases, according to more or less similar laws. In the case of tensile strength and specific gravity, no law could be found; these quantities, in fact, seemed to be independent of the moisture. In the case of specific gravity, the fact is easily explained—the shrinkage in volume is equal to the diminution of moisture. In all other cases, the values increase rapidly after the stick is about half dry (20 per cent. moisture).

The relation between strength and stiffness is such that either one is a true measure of the other. The crushing strength and the average strength increase with the specific gravity.

The different properties are subject to a variation depending upon the distance from the heart. The log was sawed into 4″ × 4″ (approximately) sticks, and upon these the experiments to determine the law of this were made. The maximum strength (excepting tensile and endwise crushing), as well as stiffness, appeared to be at a distance from the heart equal to about one-quarter of the radius of the log. No relation at all could be found for crushing across grain and shearing.

It was further shown that the properties vary with the distance from the ground, and that all are a maximum at or near the butt, and that they decrease slowly as we ascend.

The deductions made from these tests, in regard to use of long-leaf yellow pine, by Prof. Johnson, are as follows :

"The long-leaf pine timber is specially fitted to be used as beams, joists, posts, stringers in wooden bridges, and as flooring when quarter-sawed. It is probably the strongest timber in large sizes to be had in the United States. In small selected specimens, other species, as oak and hickory, may exceed it in strength and toughness. Oak timber, when used in large sizes, is apt to be more or less cross-grained, knotty and season-checked, so that large oak beams and posts will average much lower in strength than the long-leaf pine, which is usually free from these defects. The butt-cuts are apt to be wind-shaken, however, which may weaken any large beams coming from the lower part of the tree. In this case the beam would fail by shearing or splitting along this fault with a much smaller load than it would carry without such defect. These wind-shakes are readily seen by the inspector, and sticks containing them are easily excluded if it is thought worth while to do so. For highway and railway wooden bridges and trestles; for the entire floor system of what is now termed 'mill' or 'slow-burning' construction; for masts of vessels; for ordinary floors, joists, rafters, roof-trusses, mill-frames, derricks and bearing piles; also for agricultural machinery, wagons, carriages, and especially for passenger and freight cars, in all their parts requiring strength and toughness, the long-leaf pine is peculiarly fitted. Its strength, as compared to that of short-leaf yellow pine and white pine, is probably very nearly in direct proportion to their relative weight, so that, pound for pound, all the pines are probably of about equal strength. The long-leaf pine is, however, so much heavier than these other varieties that its strength for given sizes is much greater.

"A great many tests have now been made on short-leaf and on loblolly pine, both of which may be classed with long-leaf as 'Southern yellow pine,' and from these tests it appears that both these species are inferior to the long-leaf in strength in about the ratio of their specific gravities. In other words, long-leaf pine (*Pinus palustris*) is about one-third stronger and heavier than any other varieties of Southern yellow pine lumber found in the markets. It is altogether likely that a considerable proportion of the tests heretofore made on 'Southern yellow pine' have been made on one or both of these weaker varieties."

TABLE I.—CONDENSED TABLE OF MECHANICAL PROPERTIES OF LONG LEAF PINE.

[Ranges reduced to 15 per cent. moisture.]

	Specific gravity.	Cross-bending tests.			Crushing endwise.	Crushing across grain.	Tension.	Shearing.	Modulus of strength at elastic limit.
		Strength, $F=\frac{3\,w\,L}{2\,b\,h^2}$	Modulus of elasticity.	Relative elastic resilience in in. lbs. per cu. in.	Strength, per sq. in.	Strength, per sq. in.	Strength, per sq. in.	Strength (mean), per sq. in.	Per sq. in. $F=\frac{3\,w\,L}{2\,b\,h^2}$
Butt logs	0.449—1.039	4,762—16,200	1,118,800—3,117,370	0.23—4.69	4,781—9,850	675—2,094	8,600—31,890	464—1,299	4,930—13,110
Middle logs	0.575—0.859	7,640—17,128	1,136,120—2,981,720	1.34—4.21	5,030—9,300	656—1,445	6,330—29,500	539—1,230	5,540—11,790
Top logs	0.484—0 907	4,268—15,554	842,000—2,697,460	0.09—4.65	4,587—9,100	584—1,766	4,170—23,280	484—1,156	2,553—11,950

TABLE II.—RELATIVE UNIT STRENGTH AND STIFFNESS OF LARGE AND SMALL BEAMS FROM SAME LOGS.

[Results reduced to 15 per cent. moisture.]

	Mean results on the larger sizes (excluding beams which failed by shearing.)			Average results of tests on 4 × 4 inch sticks in the same log.		
	Modulus of rupture per sq. in. $f=\frac{3\,W\,l}{2\,b\,h^2}$	Modulus of strength at elastic limit per sq. in. $f'=\frac{3\,W'\,l}{2\,b\,h^2}$	Modulus of elasticity. $E=\frac{W\,l^3}{4\,D\,b\,h^3}$	Modulus of rupture per sq. in. $f=\frac{3\,W\,l}{2\,b\,h^2}$	Modulus of strength at elastic limit per sq. in. $f'=\frac{3\,W'\,l}{2\,b\,h^2}$	Modulus of elasticity. $E=\frac{W\,l^3}{4\,D\,b\,h^3}$
	Pounds.	*Pounds.*		*Pounds.*	*Pounds.*	
3 sticks, 4 × 6 inches	11,363	9,453	2,330,947	11,202	8,025	1,731,362
17 sticks, 4 × 8 inches	13,130	10,289	2,456,441	11,594	8,715	1,779,911
1 stick, 6 × 12 inches	9,915	8,710	2,105,680	12,326	8,203	1,821,280
2 sticks, 7 × 14 inches	10,025	8,505	1,948,400	11,416	8,221	1,790,138
1 stick, 8 × 16 inches	10,765	8,340	2,035,000	12,473	9,350	1,924,450

DISCUSSION.

MR. W. C. FURBER.—In answer to some of the questions raised regarding the comparative strengths of the long-leaf and short-leaf yellow pine, it may be of interest to give the results of some few tests of full-sized sticks of some joists, which were made under my supervision for the new Harrison Building at Tenth and Filbert Streets. There were eleven sticks broken of 2″×10″×13′ clear span of the long-leaf pine—the modulus of rupture varying between 5,616 and 11,468. The lower values were for sticks with knots in the upper and lower fibres of the middle third of the span—knots of considerable size outside of this middle third seemingly having no detrimental effect. The higher values were for sticks almost or entirely clear of knots. These sticks of the long-leaf variety exhibited little tendency to buckle, and broke with little notice at the different moduli given above with a short fibre, some sticks exploding and flying into small pieces. These results agree closely with Lanza's published tests on yellow pine, in which he gives moduli of 5,092 to 11,360. None of these beams showed any tendency to longitudinal shearing along the neutral surface.

Four tests were made of the short-leaf pine, with moduli of from 8,000 to 10,096. The lowest value was for a stick with some knots; the other three were clear. All of this lumber showed a much greater deflection than the long-leaf, and a greater tendency to buckle. It frequently failed by the bottom fibres splitting off.

I hope soon to present the photographs showing these timbers before and after the tests.

ANNUAL REPORT OF THE BOARD OF DIRECTORS.

FOR THE FISCAL YEAR 1893.

Presented at the Annual Meeting, January 20, 1894.

TO THE ENGINEERS' CLUB OF PHILADELPHIA.

GENTLEMEN:—In compliance with the requirements of the By-Laws, the Board of Directors beg to offer the following statement of the affairs of the Club for the year ending December 31, 1893.

During the year there have been eighteen regular meetings of the Club, at which there was an average attendance of forty-six; the maximum attendance being sixty-eight, and the minimum thirty-two.

The report of the Board of a year ago called the attention of the Club strongly to the necessity of meeting in some way, our constantly increasing deficit, and the amendment to the By-Laws which was proposed for the purpose of increasing the dues was defeated by a very few votes. As the year became older, however, it was evident that something must be done to increase the funds available for running the Club, and the amendment for increasing the dues was again proposed, and this time carried. This, it is believed, will give the Club sufficient funds to carry on the year's work without any deficit, and at the same time admit of the re-payment in part, of the loans made to fund the present deficit.

The Board has had made a careful analysis of the accounts of the Treasurer, and finds that the actual amount of money received from dues, initiation fees, advertisements, and all other sources which could be called legitimate sources of income to the Club for the year 1893 amounted to $4447 36

The actual expenses incurred during the year amounted to 4751 21

Thus adding to our actual deficit during the year $303 85

A careful estimate on the same basis, of the probable income during the year 1894, making reasonable allowance for loss of members due to increasing the dues, shows the probable amount available to be................. $5875 00

A reasonable estimate of the actual cost of running the Club, curtailing none of the privileges of members but allowing of no unusual expenditures, is 4765 00

Adding to this 20 per cent. of the dues, which must be set aside as a sinking fund,.. 960 00

Will make the total out-go $5725 00

leaving a small margin, but on the right side of the ledger. The Board adds to this report, as an appendix, a statement showing clearly how these figures are reached. It will thus be seen that the amount of increase in the dues could not have been less than was adopted, but that there is every prospect, with a proper management of the affairs of the Club, that a year from now will see one-half at least of the present indebtedness of the Club cleared off.

The condition of the Club at the end of the year, crossing off all bad, and probably bad, accounts, shows that the good money assets of the Club amounted to	$534 06
The total liabilities of the Club, including every known account against the Club, amounted to	2227 86
Leaving an actual deficit at the end of the year	$1693 80

of which $303.85 is chargeable to the year 1893. There is every prospect of this amount being cleared off in the two years for which the greater part of the loan is to run.

During the year, a number of attempts have been made to increase the interest of the members of the Club on its social side, first of which was the meeting together of a number of the members on Club night to have a dinner together before the meeting of the Club. This was followed by social meetings of the Club held on Saturday evenings between the regular meetings.

In addition to this the House Committee has added to the facilities in the card room, and had planned to fit up the third story front room for a billiard room, when the serious financial condition of the Club caused the project to be temporarily abandoned.

On the invitation of Mr. S. T. Wellman, of the Wellman Iron and Steel Company, a party of thirty-four members of the Club had a very pleasant visit to that works in June.

A Committee of the Club was appointed for the purpose of taking care of the visiting engineers who came to Philadelphia in August, and the thorough manner in which their work was carried out made the visit of these gentlemen one of the most pleasant events in their American tour.

A reception tendered the French Delegation in the Club House was most successful and enjoyable, a large number of prominent citizens of Philadelphia uniting with the Club in honoring its guests.

The appointment by the President of delegates to represent the Club in the Union Committee appointed to procure an authoritative expression of public opinion with regard to water supply, street cleaning, etc., which, although so far resulting in nothing tangible, is a step toward interesting the Club in the affairs of the city, which your Board hope will be carried much farther in the future.

A Committee of the Club was also appointed to complete the Chicago Fund. $850 was paid to the Committee in Chicago, and the balance of $49.50 still remains in the Trustees' hands for disposition by the Board or the Club. The headquarters in Chicago were well maintained and were of assistance to visiting engineers, both American and foreign, and the results of the undertaking cannot but be gratifying to the members.

The use of the Club House was tendered to the Alumni of the Rensselaer Polytechnic Institute during their meeting in Philadelphia.

For the benefit of the Club the Information Committee has purchased during the year a lantern and screen, by the use of which our meetings are made much more satisfactory.

During the year the Board has had sixteen meetings, nine regular and seven special, and it is gratifying to know that at only one meeting was the Board without a quorum. Early in the year Director David Townsend resigned, and Mr. Wilfred Lewis was elected in his stead.

The Publication Committee during the year issued four numbers of the PROCEEDINGS. The accidental loss of a portion of the manuscript seriously delayed the issuance of the July number.

The question of allowing papers to be printed in advance of their appearing in our PROCEEDINGS has been discussed, but no definite rule has been adopted by the Committee. The cost of the PROCEEDINGS to those intending purchase at the beginning of the year was 75 cents a number to non-members and 50 cents to members, and this latter price has been reduced by the Committee to 35 cents, except where numbers are rare.

The Committee has also decided that, instead of reprinting papers, hereafter members reading papers can procure twenty-five copies of the PROCEEDINGS, or more if ordered in advance, at the net cost to the Club, which is practically at the same rate, or even less, than that for which reprints could have been obtained.

The Committee has now on hand the preparation of an index to the PROCEEDINGS, extending over ten years, and it is believed that this index will make the PROCEEDINGS much more valuable for reference.

The thanks of the Board are due to Messrs. Klauder, Boericke, Dunlap and Griffith, Active Members of the Club, for the large amount of assistance rendered by them in preparing PROCEEDINGS, and for undertaking the work of preparing the index.

The office has record of the death of four members of the Club during the year:

William W. Thayer, who died March 14, 1893.
James Carstairs Burton, who died May 30, 1893.
Thomas M. Cleeman, Past President, who died November 16, 1893.
Joseph D. Potts, who died December 3, 1893.

The additions to the membership have been forty-two active and seven associate, making a total of forty-nine. Thirteen active members were dropped from the rolls January 1, 1893, under the By-Laws.

The number of resignations during the year was thirty-six from active membership and two from associate membership, making a total of thirty-eight.

The following table gives the number of members in the Club on the 31st of December, 1893:

	Resident.	Non-Resident.	Total.
Honorary	0	1	1
Active	271	163	434
Associate	13	4	17
Total	284	168	452

A comparison with the record of last year will show that the number of resident members has increased by eight, and that of the non-resident has decreased by thirteen.

The Girard Estate, just before the end of last year, notified the Board that the rent of the house would be increased $100, making the amount $1,100 per annum. After numerous attempts to have the rent remain at the old figure, the Board accepted the increase for the year ending July 1, 1894.

The Girard Estate has thoroughly renovated (papering and painting), the fourth and fifth floors and the first floor back.

The change in janitor has materially bettered the sanitary condition of the house.

The Information Committee provided during the year a very interesting series of papers and discussions, those following the summer vacation being naturally largely connected with the World's Fair.

The list appended gives the principal papers read at the different meetings during the year:

January 7th.—"Memorial of Joseph N. DuBarry;" "The Scientific Results of the Peary Expedition," by Prof. Angelo Heilprin.

January 21st.—"Report of Board of Directors;" "Annual Address of Retiring President."

February 4th.—"The West Sterilizer for Water and Milk," by Dr. Henry Leffman.

February 18th.—"The Baldwin Compound Locomotive," by S. M. Vauclain.

March 4th.—"Wood Structure in its Relation to Mechanical Purposes," by Prof. Joseph T. Rothrock.

March 18th.—"Bridges of Philadelphia," by George S. Webster.

April 1st.—"The Burning of Portland Cement," by Pierre Giron.

April 15th.—"The Development of the Tilly Foster Iron Mine," by Edward K. Landis.

May 6th.—"Memorial of W. W. Thayer;" "Engineering in Mexico," by John Birkinbine; "The Grinding of Portland Cement," by Pierre Giron.

May 20th.—"Load for Ball Bearings,—Topical Discussion;" "Vertical Pressures for High Masonry Walls,—Discussion."

June 17th.—"Modern Office Buildings," by C. H. Roney.

October 7th.—"Krupp's Exhibit at the World's Fair," by John Birkinbine; "Bethlehem Iron Company's Exhibit," by Lieutenant William H. Jaques.

October 21st.—"Pennsylvania Railroad Exhibit," by John C. Trautwine, Jr.; "The Movable Sidewalk and the General Electrical Company at Chicago," by John Birkinbine.

November 18th.—"Riveting Pressures for Bridge and Boiler Work."

December 2d.—"Some Novelties in Bevel Gearing," by Max Uhlman.

December 16th.—"Mechanical Engineering Features at the World's Fair," by A. Falkenau.

APPENDIX.

	Apparent income for 1893.	Actual receipts.	Crossed off books.	Apparent income for 1894.	Estimated receipts in 1894.
1891 Dues.					
Due Jan. 1, 1893......	$112 50				
Paid	....	$5 00			
Crossed off	....	....	$15 00		
Unpaid	....	....	....	$92 50	
1892 Dues.					
Due Jan. 1, 1893......	350 00				
Paid	....	160 00			
Crossed off	....	....	20 00		
Unpaid	....	....	....	170 00	$10 00
1893 Dues.					
Billed, Jan , 1893......	3,595 00				
New Members.........	520 00				
Paid	....	3,477 50			
Crossed off	....	....	172 50		
Unpaid	....	....	....	425 00	250 00
1894 Dues.					
Paid in advance	....	14 83			
Billed, Jan., 1894......	....	....	....	5,085 00	4,800 00
Advertisements.					
Previous to 1891	80 00				
Unpaid	....	....	....	80 00	
Due Jan. 1, 1892.........	93 50				
Paid	....	17 50			
Unpaid	....	....	....	76 00	
Due Jan. 1, 1893.........	183 50				
Paid	....	*103 50			
Commission	....	....	2 50		
Unpaid	....	....	....	78 00	15 00
For 1893, 3 Nos..........	654 00				
Paid	....	*522 50			
Commission	....	....	16 50		
Unpaid	....	....	....	115 00	50 00
For 1894, 4 Nos..........	....	....	....	872 00	700 00
Proceedings, Sales, etc.					
Due, Jan. 1. 1893......	11 00				
Paid	....	10 50			
Unpaid	....	....	....	50	
Additional sales	136 03				
Paid	....	136 03			
For 1894	....	....	....	50 00	50 00
Totals	$5,735 53	$4,447 36	$226 50	$7,044 00	$5,875 00

*These figures do not agree with those on the Treasurer's Statement—the differences being paid from balances due by Club.

	Expenditures for 1893.	Estimate for 1894.
Salaries	$915 00	$1065 00
Proceedings	1049 82	1000 00
House	1464 45	1500 00
Lunches	492 50	450 00
Printing notices	277 05	300 00
Stamps, etc.	359 17	360 00
Treasurer's Office	14 55	15 00
Library	24 77	15 00
Information Committee	86 54	45 00
Miscellaneous	16 39	15 00
Sinking Fund	50 97	960 00
	$4751 21	$5725 00

Good Assets, December 31, 1893.	
Cash Balance	$64 64
Dues, 1892	10 00
Dues, 1893	250 00
Advertisements, 1892	15 00
Advertisements, 1893	50 00
Due on small accounts	43 95
Balance Chicago Fund	49 50
Sinking Fund	50 97
	$534 06

Liabilities, December 31, 1893.	
Prepaid Dues	$14 83
M. R. Mucklé, Jr. & Co.	80 00
Prepaid Advertisements	22 00
J. C. Trautwine, Jr.	73 01
Globe Printing House	252 27
Bills Payable	1400 00
Henry Veit	50 00
D. A. Partridge	7 20
Sherman & Co	53 55
Rent	275 00
	$2227 86

Publication Committee, 1893.

Expenditures.	
Printing:	
X, 1	$226 99
X, 2	244 47
X, 3	137 30
X, 4	120 11
Reprints	88 00
Illustrations	115 20
Postage	93 90
Wrappers	14 75
Sundries	9 10
Total	$1049 82
Loss on Proceedings	$30 57

Receipts.	
Advertisements:	
X, 1	$245 00
X, 2	236 00
X, 3	173 00
X, 4	173 00
Subscriptions	37 00
Sales of New and Back Numbers	68 00
Reprints	87 25
	$1019 25

Printing Notices, Records, etc.	$277 05
Printing and Stamped Stationery for Secretary's Office	257 25
Printing for Treasurer's Office	3 25
	$537 55

ANNUAL REPORT OF THE TREASURER,

FOR THE FISCAL YEAR 1893.

Presented at the Annual Meeting, January 20, 1894.

To the Engineers' Club of Philadelphia.

GENTLEMEN:—The Treasurer submits the following report:

RECEIPTS—CASH.		DR.
To balance from 1892		$299 24
To Dues:		
Dues for 1891 paid in 1893	$5 00	
" 1892 " "	160 00	
" 1893 " "	3477 50	
" 1894 " "	14 83	
	———	3657 33
To Advertisements:		
Advertisements for 1891 paid in 1893	$17 50	
" 1892 " "	85 00	
" 1893 " "	507 00	
	———	609 50
To PROCEEDINGS:		
1892 accounts paid in 1893	$10 50	
1893 Sales	51 78	
" Reprints	45 25	
" Subscriptions	39 00	
	———	146 53
To Chicago Fund		568 50
" Loan account		1400 00
" Donations		152 00
" Special Loan		22 20
" Other sources		2 33
Total receipts, 1893		$6857 63

EXPENDITURES—CASH.	1892	1893		CR.
By Salaries:	1892	1893		
Secretary	70 +	150	$220 00	
Treasurer	80 +	25	105 00	
Janitor		245	245 00	
Secretary's Assistant		495	495 00	
			———	$1065 00

By House Expenses:		
Rent	$1025 00	
Gas	149 55	
Coal	163 25	
Ice	18 30	
Sundry repairs and supplies	126 35	
		$1482 45
By Furniture and Fixtures:		
Lantern	$31 25	
Screen for Lantern	12 75	
Typewriter Cabinet	20 00	
Picture Frame	2 60	
Telephone	10 00	
Rent of Piano	10 00	
		86 60
By Notices, Records, etc.:		
Paid on 1892 account	$325 25	
" 1893 "	258 00	
		583 25
By Proceedings:		
Paid on 1892 account	$927 91	
" 1893 "	684 44	
		1612 35
By Secretary's Office:		
Stamped Envelopes	$215 50	
Letter Heads and Other Stationery	65 00	
Postage and Small Supplies	94 92	
		375 42
By Treasurer's Office		12 20
" Luncheons		517 50
" Chicago Fund		899 50
" Sinking Fund		50 97
" Periodicals for Library		24 57
" Gas for Lantern		31 40
" J. Christie, to repay loan		22 20
" Notary's Fee, 1893		2 50
" Sundries		27 08
Total expenditures in 1893		$6792 99
Balance, January 1, 1894		$64 64

Respectfully submitted,

T. Carpenter Smith,

Treasurer.

ABSTRACT OF MINUTES OF THE CLUB.

Business Meeting, January 6, 1894.—President John Birkinbine in the chair. Seventy-two members and visitors present.

Major J. W. Powell, Director of the United States Geological Survey, gave a very interesting talk on "The Engineering Problem of Irrigating Large Areas," illustrated by maps showing the mean annual rainfall, the mean annual run-off and the comparative elevation of different sections of the United States, also a chart showing diagramatically the proportion of improved land to the total area of the different countries of the world. At the conclusion of his remarks, a unanimous vote of thanks was tendered Major Powell for his interesting address.

Annual Meeting, January 20, 1894.—President John Birkinbine in the chair. Sixty-seven members present. In the absence of the Secretary, Mr. Strickland L. Kneass acted as Secretary *pro tem.*

The President asked permission of the Club to change the order of business for the evening, postponing the Annual Address and reports and the announcement of the results of election of officers until later in the evening. It was so ordered.

The following resignations from Active Membership were presented and accepted: Messrs. Horace W. Sellers, M. P. Janney, Charles H. Haupt, B. C. Batcheller, I. N. De Haven, William Swift, William H. Thorne, S. T. Wellman, W. Brooks Cabot, H. G. Stewart, F. Rosenberg, E. V. d'Invilliers, W. H. Sayen, Coleman Sellers, Jr., H. L. Butler, E. L. Corthell, H. M. Sperry, W. H. Baldwin, Charles W. Buchholz, A. Marichal, William F. Sellers, C. S. d'Invilliers and J. M. Whitham. The resignations from Associate Membership of Messrs. Albert Priestman and S. L. West were also presented and accepted.

The Tellers reported that Messrs. Hugo L. Hund, E. A. W. Jefferies, Andrew Callahan, Jr., and Thomas J. Carlile had been elected to active membership, and Messrs. George F. Payne and De Louie Tice to associate membership.

The Secretary *pro tem.* read a letter from Hon. M. Russell Thayer, presenting a photograph of his son, William W. Thayer, active member of the Club, whose death occurred during the past year, and it was directed that a vote of thanks be tendered Judge Thayer for this gift.

The Trustees of the Sinking Fund were called upon for a report, and in the absence of Mr. James Christie, the chairman, Mr. E. K. Landis reported that, owing to the serious illness of Mr. Christie, it had been impossible to hold a formal meeting, but that it was the intention of the Trustees to declare a dividend at an early date.

The report of the Board of Directors for the year 1893 was read by the Secretary *pro tem.*, after which Mr. T. Carpenter Smith, Treasurer, presented his report for 1893. These two reports were then discussed by several of the members present, and, as they contained so many figures that it was impossible to understand them from the simple reading, it was moved and carried that the reports be printed in full and sent to the members of the Club in advance of the next meeting, in order that they might then be discussed intelligently.

Mr. John Birkinbine, President, then delivered the Annual Address.

The Tellers reported that 128 legal votes had been cast, and the following candidate were declared elected:

President:
JOHN C. TRAUTWINE, JR.

Vice-President:
A. FALKENAU.

Secretary:
L. F. RONDINELLA.

Treasurer:
GEORGE T. GWILLIAM.

Directors:
EDWARD K. LANDIS,
SILAS G. COMFORT, CHARLES L. PRINCE.

Mr. John Birkinbine, retiring President, then introduced the President-elect, Mr. John C. Trautwine, Jr., who made a few appropriate remarks.

BUSINESS MEETING, February 3, 1894.—President John C. Trautwine, Jr., in the chair. Fifty-two members and visitors present.

The minutes of the annual meeting, January 20, 1894, were amended by inserting: "The Auditing Committee reported that they had examined the Treasurer's books and vouchers for 1893 and found them correct." The minutes were then approved.

Upon motion the consideration of the annual reports of the Board of Directors and the Treasurer were deferred until after the paper for the evening was read.

Mr. Edward K. Landis read a paper on "The Magnetic Concentration of Iron Ores," and Mr. John Birkinbine presented a written discussion of the paper.

The report of the Board of Directors was then taken up, and, after considerable discussion, a motion was made and carried to adopt it, with the thanks of the Club for the valuable services rendered by the outgoing Board.

It was also moved and carried that the report of the Treasurer be accepted.

The President announced that the Publication Committee had recently been very ably assisted by Messrs. Rudolph H. Klauder and Rudolph Boericke, and that he had appointed them auxiliary members of that committee.

REGULAR MEETING, February 17, 1894.—President John C. Trautwine, Jr., in the chair. Fifty-three members and visitors present.

Mr. W. B. Riegner read a paper on "The New Falls of Schuylkill Bridge of the Philadelphia and Reading Railroad Company."

Mr. John C. Trautwine, Jr., called the attention of the meeting to an interesting problem which had occurred in supplying the village of Frackville from the Mud Run Reservoir in Schuylkill County.

Mr. Jones Wister, of the committee appointed for the purpose, presented a memorial of our deceased member, Mr. Joseph D. Potts.

BUSINESS MEETING, March 3, 1894.—President John C. Trautwine, Jr., in the chair. Seventy-six members and visitors present.

Resignations of Active Membership were presented from Messrs. F.W. Sargent and

John W. Cloud. The former was accepted, and, upon motion of Mr. Joseph T. Richards, the President was requested to appoint a committee of three to confer with Mr. Cloud with a view to the withdrawal of his resignation.

The Tellers reported that eighty-five legal votes had beeen cast, and that the following gentlemen were elected to Active Membership: Messrs. Walter L. Webb, Oliver B. Finn, Thomas B. Main, D. Guy Anderson, I. Wendell Hubbard and Ralph Crump.

Prof. Edgar Marburg read a paper on "Comments on Current Practice in the Designing of Plate Girders." The subject was discussed orally by Messrs. A. W. Barnes, James Christie, Joseph T. Richards, C. R. Grimm and John Birkinbine.

Mr. J. Chester Wilson presented a paper on "The Old Viaduct Bridge over the Conemaugh." The subject was discussed orally by Messrs. George B. Roberts and Joseph T. Richards.

REGULAR MEETING, March 17, 1894.—President John C. Trautwine, Jr., in the chair. One hundred and two members and visitors present.

The Secretary read a communication from Mr. J. S. Robeson, which was called forth by the discussion, at the last meeting, of Prof. Marburg's paper on "Comments on Current Practice in the Designing of Plate Girders."

Mr. E. R. Keller made some interesting remarks on "Some Results Obtained in the Government Investigations of American Timbers," illustrated by large plates which he had prepared. The subject was discussed by Mr. W. C. Furber.

Mr. Frederick H. Lewis read a paper on "The New Building Law of the City of Philadelphia." The subject was discussed by Messrs. Amory Coffin, L. M. Haupt, Stacy Reeves, W. W. Stevens, W. C. Haddock, W. C. Furber, Amos W. Barnes, C. H, Roney and Edgar Marburg.

The Secretary read a communication from the Society of German Engineers of Berlin, thanking the Associated Engineering Societies for the arrangements made for entertaining members of their Society in Chicago, and the facilities offered them for getting information in that and other cities.

The Secretary also presented a communication from Mr. O. Chanute, President General Committee of Engineering Societies, stating that there remained an unexpended balance of 10 per cent. from the fund subscribed for the maintenance of the Engineering Headquarters at Chicago, and enclosing a check for the Club's portion of this amount—$85. This has been placed in the treasury of the Club.

The President stated that he had secured for the Club a valuable collection of pamphlets from the engineer's office of the Brooklyn Bridge, and also that he had represented the Club at a recent reception of the Boston Society of Engineers.

Mr. Collins, President of the Technischer Verein, invited the members of the Club to attend their meeting of March 24th, when they would also take up for consideration the new building law.

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

Special Meeting, January 13, 1894.—Present: President John Birkinbine, Vice-President F. H. Lewis, Directors Strickland L. Kneass, H. W. Spangler, John L. Gill, Jr., W. B. Riegner, the Treasurer and the Secretary.

Prof. Spangler presented a draft of the report of the Board of Directors, and he was advised, in preparing the formal report for acceptance, to emphasize the encouraging points in the year's work as much as possible.

The Treasurer's report for 1893 showed:

Balance, January 1, 1893	$ 299 24	
Total receipts in 1893	6,533 39	
		$6,832 63
Total expenditures in 1893		6,767 99
Balance, January 1, 1894		$64 64

Regular Meeting, January 20, 1894.—Present: President John Birkinbine and Directors H. W. Spangler, Wilfred Lewis, John L. Gill, Jr., W. B. Riegner, Henry J. Hartley and Strickland L. Kneass.

A telegram was presented from the Secretary, in which he stated his inability to be present, and Mr. Strickland L. Kneass was appointed to act as Secretary *pro tem.*

The Treasurer's report for December showed:

Balance from November	$116 12	
Amount received in December	283 33	
		$399 45
Amount expended in December		334 81
Balance, December 30, 1893		$64 64

The Publication Committee reported total cost of Proceedings for the year 1893, $1,049.82, and total receipts, $1,019.25, thus making the loss on Proceedings for the year $30.57. The cost of notices, records, etc., and for printing for the Secretary's and the Treasurer's offices amounted to $537.55 for the year 1893.

The Committee also announced that in future members whose papers are published in the body of the Proceedings in large type will be entitled to 25 copies of that Proceedings free, and also 25 copies at 10 cents each; and when their paper is published in "Notes and Communications," or as "Discussion," they will be entitled to 25 copies at 10 cents each. Reprints may be ordered at the same price as usual, but it is the opinion of the Committee that they should not be issued without discussion.

The report of the Treasurer and that of the Board of Directors was read, and after some discussion, approved and ordered to be presented at the annual meeting of the Club.

Organization Meeting, January 27, 1894.—Present: President John C. Trautwine, Jr., Vice-President A. Falkenau, Directors John L. Gill, Jr., W. B. Riegner, Henry J. Hartley, Silas G. Comfort, Edward K. Landis, Charles L. Prince, the Secretary and the Treasurer.

The President appointed the following standing committees for the year 1894, the first named in each case being chairman:

Finance.—Messrs. Gill, Christie and Landis.

Membership.—Messrs. Christie, Riegner and Falkenau.

Publication.—Messrs. Comfort, Gill and Prince.

Library.—Messrs. Hartley, Riegner and Comfort.

House.—Messrs. Landis, Hartley and Riegner.

Information.—Messrs. Falkenau, Prince and Comfort.

The Secretary was instructed to prepare a revised List of Members for early issuance, and to correspond with regard to its being gotten out by an advertising agent, as in the past two years.

Regular Meeting, February 17, 1894.—Present: Vice-Presidents James Christie and A. Falkenau, Directors W. B. Riegner, John L. Gill, Jr., Edward K. Landis, Silas G. Comfort, the Secretary and the Treasurer.

The Treasurer's report for January showed:

Balance from December 30th	$64 64	
Amount received during Jannary	1,796 61	
		$1,861 25
Amount expended during January		698 95
Balance, January 31, 1894		$1,162 30

The Secretary presented a letter from Prof. J. B. Johnson, of Washington University, St. Louis, enclosing a circular-letter which he had prepared, to be sent to the members of the Engineering Societies, requesting that they use their influence with members of Congress to have a bill, called the Manderson-Hainer bill (S. 1,353 and H. 4,897), providing for the extension of second-class rates to the publications of benevolent or fraternal societies and to incorporated institutions of learning, amended so as to include the publications of scientific, engineering and other strictly professional societies, and to urge its early adoption in the amended form. A sufficient number of these circular-letters having been forwarded by Prof. Johnson, the Secretary was instructed to distribute them to members of this Club with the next meeting notices. The Secretary was also instructed to correspond with the framers of the bill and the Representative from this District on behalf of the Board of Directors.

The Membership Committee reported that there were on hand one application for associate and five applications for active membership, and it was ordered that the next meeting of the Club be a business meeting, at which these should be acted upon.

Mr. Christie, as Trustee of the Chicago Fund, presented the following statement:

Dr.		Cr.	
1893.		1893.	
March 7. To cash	$384 00	May 4. By cash sent to Chicago,	$500 00
March 20. To cash	45 00	June 20. By cash sent to Chicago,	350 00
April 24. To cash	90 00	1894.	
May 8. To cash	236 50	February 21. By cash returned Club	49 50
June 5. To cash	115 00		
July 5. To cash	29 00		
	$899 50		$899 50

Mr. Christie also reported that the Sinking Fund to pay off the Club's two-year notes had been deposited in the Manayunk National Bank in the name of the Engineers' Club Trustees, and that the signatures of all three Trustees had been filed there.

The Treasurer was authorized to deposit the funds of the Club with the Girard Life Insurance, Annuity and Trust Company, of Philadelphia.

Regular Meeting, March 17, 1894.—Present: President John C. Trautwine, Jr., Vice-President A. Falkenau, Directors W. B. Riegner, John L. Gill, Jr., Silas G. Comfort, Charles L. Prince and the Secretary.

The Treasurer's report for February showed:

Balance on hand, February 1st	$1,162 30	
Amount received during February	656 75	
		$1,819 05
Amount expended during February		924 75
Balance on hand, February 28th		$894 30

The Secretary presented the following communications:

From Senators Manderson and Cameron, and Representatives Hainer and Adams in answer to the letter of the Board asking for their support of the Manderson-Hainer bill and its amendment.

From Mr. F. Collingwood, Secretary of the American Society of Civil Engineers, offering copies of a publication in English, describing engineering works by Portuguese engineers, published by the Society of Civil Engineers of Portugal. The Secretary was instructed to request Mr. Collingwood to send as many copies as could be apportioned to our Club, at our expense for expressage.

The Publication Committee presented estimates from three printers for publishing 800 copies of the General Index of the first ten volumes of our Proceedings.

Upon motion of Mr. Gill, the Secretary was instructed to send out, with the next meeting notice, a statement regarding the Index, and to request contributions to bear the expense of its publication, with a blank form of subscription enclosed.

The President reported that the engineer's office of the Brooklyn Bridge had sent the Club a valuable series of pamphlets, which were well worth binding, and the matter was referred to the Library Committee, with power to act.

PROCEEDINGS

OF THE

ENGINEERS' CLUB OF PHILADELPHIA

ORGANIZED DECEMBER 17, 1877.

NOTE.—The Club, as a body, is not responsible for the statements and opinions advanced in its publications.

Vol. XI.] APRIL–JUNE, 1894. [No. 3.

IX.

THE BAPTISM OF THE GREAT NIAGARA TUNNEL.

By EMILE GEYELIN, Visitor.

Read, April 7, 1894.

Mr. President and Members of this Club.

GENTLEMEN:—At the request of some of your members, I am before you this evening to point out to you several engineering and mechanical features which presented themselves in the construction of certain turbines recently put into operation at Niagara Falls. The water let on to these turbines, the first to make use of the Niagara Tunnel, served for its baptism. May it grow in usefulness, is the hope of all those seeking progress. Before proceeding let us take a topographical view of the exact locality under consideration. While every member undoubtedly has a fair notion of the conception and successful carrying out of this gigantic work, known as the Niagara Tunnel, which is to serve for the outlet of the waters from future great hydraulic motors, for the information of the few who have given the matter but little consideration, I would say that by an Act of the New York Legislature, the Cataract Power Company received the right to construct a tunnel for the purpose of creating a water-power of

an estimated capacity of 100,000 horse-power with the additional right of duplicating the same. The same company obtained from the Dominion of Canada the right to put a third tunnel on the Canada side of a still greater capacity than both combined on the American side, namely, 250,000 horse-power.

While great credit is due to Mr. N. B. Gaskill, the late president of the Cataract Construction Company, Dr. Coleman Sellers, and other engineers, it required broad-minded capitalists to sink $1,200,000 in the earth so as to be able to use up another $1,000,000 or more in creating a gigantic water-power. The greater part of this work, I am glad to be able to say, is done at this hour; that is, as far as regards the tunnel, it is all done; leaving yet a good deal to be done in placing the hydraulic motors and dynamos to create and absorb the power. This tunnel throughout is lined with two thicknesses of brick, laid in Portland cement. It presents an interior area of 314 square feet, while its total length is 6,200 feet. It starts about 4,200 feet above the Falls, from a depth of 145 feet below the upper level of the Niagara River and by varying incline terminates at about 50 feet below the new Passenger Suspension Bridge, 250 feet below the cliffs, so much admired in conjunction with the great Niagara Falls.

Let it be here understood that this great tunnel is in fact nothing more than a waste way for the waters from the turbines from which this great power is to be obtained. Standing on the Suspension Bridge and looking down to the right and noting 180 feet below, the tiny rivulet now discharging from this great tunnel, it is hard to realize that, taking into account the considerable wash waters from the paper mill, as well as the percolation through the rocks at the tunnel, it represents actually the labor corresponding to 3,000 horse-power. How puny is the amount when compared with the vast body of water of the great Falls, approximately estimated at 5,800,000 horse-power.

Let us descend from the cliffs and enter the tunnel at its mouth. In ascending towards the wheel pits, we find a gradual upward incline with the view of a rapid discharge of the water to come from the turbines; this incline is at the average rate of one foot in one hundred, or about sixty (60) feet in the total length of

6,200 feet. We reach first a smaller tunnel of 7 feet interior diameter that ascends to the wheel pit of the Niagara Falls Paper Company. Continuing our ascension of a few hundred feet more, we reach the head of the tunnel at the wheel pit of the Cataract Construction Company. This pit, which I may describe as being some 1,500 feet from the banks of the Niagara River, is some 25 feet wide, 200 feet long and admits of 10 turbines each of 5,000 horse-power, 3 of which are this day on the ground ready to be put into position.

Returning now to the mouth of the small tunnel we may notice an interesting piece of stone work, namely, the part which forms the junction of the two tunnels; every stone is made of Brandywine granite, one of the hardest of stones. It was a wise decision in adopting so hard a material at this place. When in the near future 520 cubic feet of water per second comes rushing at an angle of 60 degrees against the great body of 7,000 cubic feet of water per second, the material which controls its boundary needs to be hard indeed.

Ascending now the small tunnel we reach its cast-iron inlet at the Niagara Falls Paper Company's wheel pit. This pit is located about 800 feet from the banks of the Niagara River, from which river an inlet 30 feet wide and 12 feet deep takes the water through a raceway of 220 feet length to the iron penstock.

As the contents of this pit are the main objects of this address, I present some of the dimensions—its length is 42 feet, breadth 28 feet, and depth 168 feet. This pit, with its many pockets to receive girders, like the space for the tunnel, has been blasted out with dynamite from the solid rock.

In April, 1892, the firm of R. D. Wood & Co., of this city, entered into a contract with the Niagara Falls Paper Company to construct and put into position three turbines, each of 1,100 horse-power, under 140 feet fall, the motion to be transmitted by means of upright shafts and bevel wheels to three horizontal shafts, each horizontal shaft to make 200 revolutions per minute, to be placed 154 feet above the lower level. The wheel pit and superstructure to be large enough for three more wheels.

Months before this contract was entered into, the Paper Company, then known as the Zoo Company, obtained plans for their

turbines through the Cataract Construction Company from Messrs. Escher & Wyss, of Zurich, and Messrs. Faesch & Piccard, of Geneva, both of Switzerland. Messrs. Escher & Wyss proposed eight turbines for 700 horse-power, and two turbines of 200 horse-power, to be placed at the bottom of the fall, grouped around two inlet tubes 5 feet 8½ inches diameter. Objection, we understand, was raised specially on account of the contracted inlet pipes, and further the necessary width of nearly 54 feet of the wheel pit. Objection also was found to the plans submitted by Messrs. Faesch & Piccard, who had four turbines, each of 1,400 horse-power, presented, causing the water to flow 568 feet per minute and hollow turbine shafts of 3 feet 3⅝ inches diameter, 115 feet in length, making 75 revolutions per minute without any other bearing than one at the bottom at the turbine and one at the top near the gears, 110 feet apart. Special objections were found in the manner proposed to transmit the power to the horizontal shafts, making 220 revolutions, which consisted of two pair of bevel wheels and three spur wheels for each turbine.

It was hardly wise to seek such lights in Europe.

A third plan was proposed by one of these firms which, in an ordinary condition, would present the great advantage of compactness, namely, the placing of two pair of horizontal turbines at the bottom of the fall and connecting thereto directly the pulp-grinding machines. As far as the turbines themselves are concerned, nothing could have been simpler, but the necessity of the attendance of these grinding machines, 150 feet under ground, and the further necessity of pumping the pulp to the top was found objectionable.

As stated above, the wheel pit is 42 feet long by 28 feet inside; this comparatively small section was only obtained after a careful study in the grouping of the gates and turbine casings around the penstocks. Every square foot of increase in the size of the pit not only would have added to the cost of excavation, but would have increased the difficulty of making a firm superstructure whereby the shafts are held in position.

The primary object in planning the component parts of the wheel pit was, first, the proper manner of bringing the water to the six turbines, and then to so proportion the water-ways as to

relieve the turbines of said water through the 7 feet diameter tunnel. This, in conjunction with a perfectly safe gate arrangement whereby the water was to be admitted or excluded at will to the turbine casings. In the second place it was necessary to so proportion and arrange the turbines and their component parts that high efficiency could be obtained when performing full duty, and to make the design such that all parts might be accessible in case of repair; also to have a sensitive and perfect control of the speed by means of balanced gates to be operated by governors on the mill floor 160 feet above it. The third consideration was to plan a superstructure that would firmly hold the bearings for the upright and horizontal shafts. And, fourth, to proportion the shafts and gears to safely transmit the motion from the turbines through the vertical turbine shafts to the horizontal shafts connected with the main shafting of the mill.

Returning now to the first division, namely, the water-ways, the case presents itself as follows: To supply six turbines, each of 1,100 horse-power under 140 feet fall, for each turbine assuming an efficiency of 80 per cent., it requires 5,200 cubic feet of water per minute, or a total of 31,200 cubic feet. It was not intended to start the six turbines at once, but only three. Furthermore, as the power of these three turbines was to be absorbed on one side of the pit, the penstock receiving the water from the head race was made to supply four turbines. Its dimension is 13 feet 6 inches diameter. This water-way is ultimately to be supplemented by a 9 feet diameter penstock, when the three other turbines are wanted. The riveting on this penstock was done in the wheel pit by means of a movable hydraulic riveter supplied from a high pressure pump and accumulator.

Two important points presented themselves regarding this first penstock. The first was that an intake should be low enough to guard against the possible filling up with ice from the surface. The second was to guard against the effects of expansion and contraction from the change of temperature. This latter point was attained by leaving an open space in the wall through which the intake passes and making a hemp packing joint protected by wire. This penstock, after it enters the wheel pit in a horizontal position, takes a right angle turn and descends 128 feet, say 8

feet below the lower level of the Fall. In the bottom section of this penstock, which there reaches a thickness of $\frac{7}{8}$ inches, there are four openings 66 inches in diameter, two of which at present, and ultimately all four, are to be provided with steel gates 66 inches in diameter, operated by hydraulic lifts, secured immediately above them. Lifting these gates, however, is only to be performed after admitting the water pressure on both sides of the valve by means of a bye-pass. Twelve feet below the outlet from the turbines is the center line of this 7 feet tunnel through which the water leaves the wheel pit. When all six turbines are running there will be, including the wash water used in the mill, a total flowage of 35,000 cubic feet per minute; in other words, it will flow at the rate of 15 feet per second.

As stated above, four openings for the turbines had to be provided in the bottom part of the penstock. These openings necessarily had to be proportionately large for the admittance of the water to the turbines, thereby very materially reducing the surface of metal. This difficulty was overcome by a series of rods holding the sides together. To reach the third turbine casing on the same side of the wheel pit it became necessary to provide a fifth temporary opening of 66 inches in diameter 13 feet above the other four, whereby the water is first taken to a truncated section of the future 9-foot penstock, from whence the water reaches the turbine casing.

Coming now to the second part, namely, the turbines and their component parts, I early saw the great advantage of adopting the inverted plan, whereby the great weight of the shafts and gears would be to a large extent counterbalanced by the upward pressure. Two main features in the turbines required special attention, namely, the movable and guide wheels had to be so planned as to give the proper speed and power necessary. The other was to have the gates and gate motions such that under the 60 pounds pressure per square inch they could be moved quickly up and down by the governors.

Regarding the proper speed of the turbines, I ought to state that it was in part controlled by the bevel wheels which transmit the motion of the horizontal shaft. I judged it unsafe to make a smaller set of bevel wheels than those now in operation, and was

therefore forced to increase the diameter of the movable wheels slightly, which brought the speed of the turbines to 260 revolutions per minute. With the view of obtaining finer lines and a greater durability of the movable wheels, the rims were made in bronze. They are 4 feet 8 inches in diameter and have thirty (30) apertures.

Regarding the gate and gate motions, we have adopted the Geyelin-Jonval Patent Gates, which are provided with stout sleeves, each weighing 2,800 pounds, sliding outside the guide wheels to hoods. When closing, these sleeves are guided by four rods, which extend above the turbine casings some 10 feet, where they are united and attached in each case to a yoke which again attaches to a lever, at end of which lever a wire rope is attached which extends to the mill floor above, passes over a shive, then drops some 10 feet and is provided with a counter-weight which largely counterbalances the gates and rod.

While the steps under the turbine shafts are there ready to receive the weight of the turbine, shaft and gears above in case of an accident, yet they are in no way intended to carry any weight while the turbines are in operation. In connection with each step there is below the turbines an adjustable guide-bearing lined with lignum vitæ, which serves to guide the turbine shafts inside the casings.

Coming now to the third consideration, in designing the superstructure to firmly hold the upright turbine shafts, special attention was brought on two main parts, namely, to the section close to the turbines receiving the motion and to the part close to the bevel pinions, delivering the motion to the horizontal shafts. In each case we provided heavy cast-iron girders, the bottom girder being 30 inches deep and 18 inches broad, supported in the center by two columns; for the upper part near the gears we have for each turbine a double harness, being also in cast iron, giving support to two ample bearings.

In addition to the above provision to steady the shafts, each shaft is provided near the gears with a thrust bearing, intended to support any up or down pressure which occurs in the different degrees of gate opening in the turbine while performing duty; thus when the turbine gates are half open, the pressure on the bearing is downward, and when full open it is upward.

We succeeded in floating the turbines with their shafts and steel pinions, the whole weighing in each case 15,500 pounds, namely: turbine, 3,700; gear, 4,950; shaft, 5,789, and bolts, 725 pounds.

Concerning the upper superstructure near the gears, we have a combination of longitudinal and transversal iron girders with braces, and supported on stout walls laid in cement, besides heavy cast-iron columns that reach from the very bottom upwards, the whole upper superstructure, not including the pedestals, representing a weight of 272,000 pounds.

The intermediate guides to the shafts, which occur every 21 feet in height, are formed by heavy 20-inch beams, placed in each case in pairs and provided with cast-iron separators, to which the pedestals are bolted. There are six of these intermediate frames designed for the guidance in each case of six turbine shafts. They are securely masoned and bolted into the rock, the six frames representing a total weight of 273,000 pounds.

Much attention was given also to the proper size of the shafts, each to transmit 1,100 horse-power at 260 revolutions per minute, the maximum distances the bearings should be and the materials they should be made of. With the view of perfect rigidity, we adopted 10 inches as a diameter, which is much above what the formula would indicate; 21 feet was taken as the safe distance between the bearings; and, finally, with the view to prevent any possible couplings getting loose on the shafts, the flanges were forged on, and in place of steel hammered iron was used.

One of the most serious difficulties in this work was to so proportion the bevel wheels that they would safely transmit the motion from the vertical turbines to the horizontal shaft, each turbine transmitting 1,100 horse-power at 260 revolutions per minute to the horizontal shaft, making 200 revolutions per minute. Had the labor to be performed by each turbine been uniform, like the labor in a cotton or woolen mill, I might have reached the conclusion of using steel gears with a somewhat finer pitch, and thus brought the circumferential velocity within safely established bounds. The reverse, however, is the case in the duty to be performed by two of these turbines, since the sudden taking off or putting on of 150 to 200 horse-power may occur at

any moment. For this reason the style of mortise gears was decided upon. From the very nature of having to depend on a softer material, wood being the transmitting element, it became necessary to increase the surface proportionately, and consequently the making of the circumference larger. Long did I hesitate before reaching the final conclusion of adopting the size of gears that I judged to be necessary, as I could find no record of any gears running 4,000 feet as a circumferential velocity per minute. Even 3,000 feet per minute was considered beyond the safe limit. One feature which I considered essential to the success of gears running such great velocity I judged we already had secured, namely, in the designing of the massive and well interlocked cast-iron framework to hold the bearings together, which bearings are on the front and rear of each gear. The second, namely, the danger against the flying apart of the rims of the mortise wheels, I guarded against by banding these wheels with heavy wrought-iron bands. The gears are 43 and 33 teeth, $5\frac{1}{2}$-inch pitch, 20-inch face of teeth, 6 feet $3\frac{32}{100}$ inches and 4 feet $\frac{80}{100}$ inches diameter.

After running successfully for five weeks I am now happy to be able to say that the turbines are peforming the full duty they are called upon to perform, the bearings are cool and the gears show no indication of weakness or tremor. The water as it leaves the turbines falls over the sides of the casings, its terrible force wholly spent on the wheels.

Before closing, permit me to say that a statement of the planning of six turbines for the Niagara Falls Tunnels and the method of transmitting the power to the mill but faintly conveys an impression of the magnitude of the work and the many difficulties which were overcome. 1,500,000 pounds of metal were needed to accomplish this result, not one pound of which was superfluous. While I designed the work, credit is due to the Camden Iron Works engineers for their assistance and to the intelligent supervision of Mr. Walter Wood. It may also interest you to learn that in the erection of this work, Frank Fish, who had charge, had no loss of life to deplore among his helpers, nor any maimed to assist—all erection was done safely by means of a 10-ton traveling crane that reached over the pit. Thus all is well that ends well.

X.

METHODS AND APPARATUS FOR DRYING WITH HEATED AIR.

BY E. M. COOK, Visitor.

Read, April 7, 1894.

THE operation of drying is one which is of the most essential importance in many industries, and leaving out of view metallurgical processes and manufactures of metals, there are few which are not to some extent concerned with it. It is of interest therefore to inquire whether economies over the present prevailing methods may not be effected. The physical laws which are involved in considering it are few, and such as are well understood. It is when we seek to apply them to practical problems that, as is frequently the case when we attempt the application of general principles, we encounter difficulties. It is not too much to say that most drying as at present carried on is conducted with little economy of time, space, heat or labor; it being frequently thought sufficient to provide a room in which to place the material to be dried, furnished with steam pipes or other means of radiating heat, but not seldom with accidental provision only for the removal of the more or less moisture-laden air. But there are some materials with which, notwithstanding much more elaborate apparatus, no economical success has heretofore been attained; and so far as they cannot be utilized undried, they are allowed to go to waste.

The entire question of drying may be considered as a contest between the occupation of much space and the consumption of much time on the one hand, and the employment of apparatus and the expenditure of artificial heat, both costly, on the other. Most materials not subject to too rapid decomposition can be dried, as has been done for ages, by the spontaneous forces of nature, the sun and the wind, without special apparatus; but usually at the cost of much time and space and of manual labor in turning and spreading them. Where circumstances admit

of the practically unlimited expenditure of these items, and the amount of moisture is not greater than can commonly be evaporated in the intervals between rains, this method, using only the gratuitous forces of nature, is the most economical. It is still in extensive use for drying crude products in the dryer regions of the world, and on the coasts of Norway and Newfoundland in curing fish.

The next step forward is the use of drying rooms with shutters or louvres, which may be closed at night and during unfavorable weather, and in which the material to be dried may be placed for convenience of handling and moving, on shifting shelves. Such is the method still largely in use in drying glue; and the large glue works in this and other cities have many acres of floors devoted exclusively to this purpose. Glue being an article of high value when finished, will bear the cost of this expensive method of drying. There are, however, many materials and circumstances which prohibit the occupation of so much time and space in drying, and in treating which notwithstanding, owing to their low value when finished, the closest economy must be observed to bring out satisfactory financial results; and here the use of apparatus and of artificial heat is indicated as a necessity. The points to be provided for are: the utilization of the largest practicable proportion of the energies employed; the convenient and efficient handling of the material; the greatest possible economies of time, space and labor. So far as these ends are attained, so far is the apparatus successful; and at the point where the economies of time and space are met by the cost of the apparatus and of its operation, the advantages are balanced and the apparatus ceases to have industrial value. In considering the question of the application of artificial heat to drying, I early reached the conclusion that the most philosophical as well as the most economical system, especially as applied to the treatment of granular material, was the use of hot air; and in the present paper I shall confine myself to this method of drying.

In drying we have to deal with and adapt ourselves to the unalterable laws of nature. The energy by which evaporation is accomplished is heat and heat only; and the amount of heat that must be expended in the evaporation of a pound of water

under atmospheric pressure is the same at whatever temperature the evaporation may take place; it follows that the more rapidly we can expend heat, provided that it be really expended in evaporation and not otherwise disposed of, the more rapidly will our material be dried. It is however, requisite that some means shall be provided for the removal of the vapor as fast as evolved, or evaporation will cease, notwithstanding the heat; and unless we can provide a vacuum, which is not readily practicable in the treatment of solids, the best medium for this purpose and in fact the only practicable one, is unsaturated air. But it is important that it shall be *unsaturated*, and as its efficiency rapidly diminishes as its condition approaches saturation, it is necessary to provide for its very frequent renewal.

The function of the air in drying is twofold. It serves to carry into the apparatus and to the material under treatment the heat by which the evaporation is to be performed; and it furnishes the medium or vehicle for bearing away the vapor. It is well known that the capacity of air for vapor is very much greater at high temperatures than at lower ones; while its capacity for heat, at best very small, its specific heat being but .238, does not increase. At 72° F. the capacity of a pound of air for vapor is about three times as great as at 42°; while at 132° it is more than twenty times, and at 172° more than eighty times as great. Yet on a windy day in March, when the air, probably below 42°, besides furnishing but little heat, has this very small capacity for carrying moisture, we find that drying goes on rapidly; while in August, with the far greater heat and larger capacity of the air, when dry, for moisture, we find that in any place sheltered from the wind, as the interior of a forest, the air becoming nearly saturated, drying almost entirely ceases, and only such vegetation is found as thrives on dampness. This offers a striking indication of the necessity of rapidly moving the air if we wish to maintain its efficiency for drying; which may be stated as a function compounded of its temperature, its relative humidity and its velocity of motion.

The more heat we can expend in evaporation in any apparatus, in a given time, the greater will be its capacity; and the less heat we dispose of in other ways, the greater will be its

economy. The most important loss of heat in drying with heated air, if the apparatus is suitably constructed to limit the loss by radiation and leakage, is that in the air discharged with the vapor; and it is here that we must look for any economy of heat. This loss is, however, to some extent one of those necessary wastes which we have to accept. It is seldom possible, in a practical operation, to realize the ultimate value of the energies we employ; and this loss is strictly analogous to that in the use of steam for heating, where we sacrifice the heat which has raised the water from its normal temperature to that at which, as condensed steam, it is discharged. It is, however, relatively greater, as we have not in air the latent heat of vaporization, of which we avail ourselves in the use of steam. As at high temperatures and at great relative humidity, or percentage of saturation, the air carries its greatest burden of moisture, under these conditions of discharge will the greatest economy of heat be found.

The relative proportion of heat lost in the air of discharge at 122° F. and 172° would be as 699 to 238,* these figures being a ratio only, and based on an assumed normal temperature of 62°, ignoring the moisture normally present in the air; but if we make an allowance for the normal moisture, which assumes importance at the lower temperatures of discharge, we shall get a still greater discrepancy, and the loss at the higher temperature will not exceed 30 per cent. of that at the lower. But as evaporation is greatly retarded as the point of saturation is approached, we are in this direction limited, and in practice it is not usually desirable to attempt a saturation exceeding 50 or possibly 60 per cent.

The expenditure of heat in evaporation is so rapid, and the amount required so great relatively to the amount of air required at high temperature to carry the vapor, that, with a discharge at high temperature and economically small volume, we find that to attain even a saturation of 50 per cent., we must employ initial temperatures which soon become inconveniently high. Thus, at a discharge temperature of 122°, half saturated, and making a suitable allowance for the normal moisture (.0075 of the weight

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* $122 - 62 \times 11.65 : 172 - 62 \times 2.16$.

of the air), we require to carry one pound of vapor, 28.23 pounds of air; and to bear in the requisite amount of heat, it must start at 288°. But at a discharge temperature of 172°, and the same normal moisture, we require but 4.46 pounds of air; and this small quantity must start at 1223° to do the appointed work.* A large class of material would not bear safely the first of these temperatures, while it is obvious that all but the most refractory would be destroyed by the latter. If we attempt a higher degree of saturation of discharge, the necessary initial temperatures rise rapidly, as the amount of the air is thereby diminished; and it must not be forgotten that even to these temperatures something must be added to make good the heat lost by radiation, and that expended in heating the material itself up to the temperature of exit. Let us consider a lower range of temperatures, and suppose

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* Saturated mixtures of air and vapor will contain with each pound of air: at 172°, .46338 pound vapor; at 122°, .08584 pound; at 92°, .03289 pound; and in proportion if partly saturated. Assume normal temperature of air (and material) at 62°, and vapor normally present at .0075 per pound of air (equivalent to a dew-point in the neighborhood of 50°). We must expend in the evaporation of one pound of water, 1116 B. T. U. (1178–62), which is the equivalent of raising one degree in temperature 4687.2 pounds of air $\left(\frac{1116}{.238}\right)$. We require to carry off one pound of vapor discharged at 172° .50 saturated, $\frac{1}{.46338 \times .50 - .0075} = 4.46$ pounds of air; to bear in the required heat, the difference of temperature of intake and discharge must be $\frac{4687.2}{4.46} = 1051°$; and our discharge temperature being 172°, the intake must be $1051 + 172 = 1223°$. At 122° .50 saturated, we must have to carry off one pound of vapor, $\frac{1}{.08584 \times .50 - .0075} = 28.23$ pounds of air; $\frac{4687.2}{28.23} = 166°$ difference of temperature of intake and discharge; and $166 + 122 = 288°$ necessary temperature of intake. At 92° .60 saturated, we must have $\frac{1}{.03289 \times .60 - .0075} = 81.73$ pounds of air; $\frac{4687.2}{81.73} = 57°$ difference of temperature; and $57 + 92 = 149°$ temperature of intake.

We expend in each case in the work of evaporating one pound of water, 1116 B. T. U.; and the heat escaping unutilized in the air accompanying the vapor, would be: at 172°, $172 - 62 \times 4.46 \times .238 = 116.8$ B. T. U.; at 122°, $122 - 62 \times 28.23 \times .238 = 338.1$ B. T. U.; at 92°, $92 - 62 \times 81.73 \times .238 = 583.6$ B. T. U. These figures show units of heat lost in the air of discharge at the respective temperatures and saturations for each pound of water evaporated.

that we have a material which will not bear a temperature above 150°. In this case, the loss of heat in the discharged air assuming great importance as we descend in temperature, we will, in the interest of economy, allow a higher saturation, say 60 per cent.; and to attain this with the permitted initial temperature, we find that we must discharge at about 92°; but at this discharge, the heat carried in the air is over 52 per cent. of that utilized in evaporation.

None of the heat contained in the air of discharge is utilized in drying; and it is evident that to avail ourselves of the economies of a high temperature of discharge we must devise a means of introducing the necessary amount of heat, limiting the volume of air, and, at the same time, avoiding the exposure of the material under treatment to the injuriously high temperatures.

This has been practically accomplished by circulating through a drying apparatus, in a continuous endless circuit, a volume of air several times greater than would be required at the temperature and saturation of the discharge to bear away the evaporated moisture; discharging continuously or intermittently a portion sufficient for that purpose. The heat demanded for the evaporation is supplied to the recirculated current from some artificial source, usually by passing its entire volume through a coil or other heater, to which is at the same time admitted air to replace that discharged. The coils, or other heat-radiating surfaces, are, in some cases, placed in the same chamber with the material under treatment, the effect being nearly the same. A fan-blower at any convenient point in the circuit maintains the circulation, and, where the form of the dryer makes it desirable, a smaller one controls and regulates the discharge. The air, in its passage over the material, parts with heat and takes up vapor; and its drying efficiency, compounded, as has been stated, of its heat, its relative humidity and its motion, is measurably impaired thereby; but at its minimum is still very considerable, and is constantly renewed as the mixture passes through the heater. If a relative humidity of 50 per cent. is maintained in the discharge, which, at considerable temperatures, gives a very high drying efficiency, this will be the least favorable condition of the current; and in this condition it will, in a suitably devised dryer,

encounter only that portion of the material which, containing all of its original moisture, will part with it with the least reluctance. The current, regenerated in its passage through the heater by the addition of heat and air, reaches its maximum of efficiency, and in this condition attacks the material which has parted with the greater part of its moisture, and, in consequence, surrenders the remainder with difficulty. A very serious defect in hot-air dryers, as commonly constructed, is in the run, or length of transit of the air over the material, being insufficient to allow of the air becoming suitably saturated before its discharge; as is conclusively shown by the small difference of initial and discharge temperatures. This is especially the case where the material, owing to its physical structure, or for other reasons, parts with its moisture with difficulty. The recirculatory system overcomes this difficulty, and by employing it the advantages of a run of any desirable length may be had within reasonable dimensions, and both the economy and capacity of a dryer be much promoted. This system was covered in some of B. F. Sturtevant's earlier patents; but its importance does not seem to have been, until recently, fully appreciated. Dryers in which it has been employed, have been put into operation in this city and elsewhere, with excellent results of economy, by the Philadelphia Textile Machinery Company, who have given much intelligent attention to its development. As commonly employed, however, under some conditions important difficulties are encountered. Many materials, in drying, evolve corrosive gases, which, if driven through a heater, rapidly destroy the radiating surfaces; others throw off dust, which coats the radiating surfaces, and, besides impairing their efficiency, becomes charred and burnt, giving rise to noxious and injurious odors. It is also not applicable to that important and economical class of dryers in which the heat is derived from sources other than radiating and conducting surfaces, notably where the gaseous products of combustion are directly used.

To meet these difficulties and adapt this system to these conditions, the current may be circulated through the dryer as before, but instead of supplying the heat by passing its entire volume over radiating surfaces, this may be done by allowing it to cir-

culate unobstructedly, except as to the parts of the dryer and its contents, and introducing into it in the course of its circuit, but before it enters the drying chamber, a portion of air, or gas, equivalent to the air of discharge, at a temperature sufficient to carry the necessary heat for evaporation. This may consist of the gaseous products of the combustion of any smokeless fuel tempered with air where desirable, or of air heated in any other convenient way, as the feature of this method consists in the manner of introducing the heat, and not in the source of the same. The temperature of the current at its maximum will be regulated by the relation of its volume to the volume and temperature of the entering hot air, and may thus be adapted to the requirements of any material in this particular, while retaining the advantage of a relatively high temperature of discharge and the great economy of the direct use of the gaseous products of combustion. Such gases entering a dryer at a high temperature would meet immediately several volumes of the partially saturated mixture of air and vapor (at the temperature of discharge), and mixing with them, would raise them to the temperature appropriate to the material under treatment. In its passage through the drying chamber, the mixture loses heat and gains humidity until, reaching the terminal point, a portion is discharged bearing out the evaporated moisture, and the remainder continues in the circuit, taking up fresh hot air or gas, and again proceeds on its mission.

With a discharge at 172° half saturated as above, and an intake of air or gas at 1223°, we can by recirculating say five volumes, bring the initial temperature at which the air strikes the material below 300°; and by increasing the volumes of recirculation, as much lower as may be desirable. Similarly in the case supposed of a material for which the temperature is limited to 150°, by recirculating several volumes we may realize the economy of a discharge at 120° or 130° without exceeding the limit imposed on the initial temperature. The *fixed* relations of temperature (the relative humidity of the discharge remaining constant) are those of the intake and discharge; and the *variable* one, the maximum temperature of the circulated current; which will be the initial temperature in the drying chamber, and which

will be determined as above, by the number of volumes recirculated. It follows, therefore, that we can only raise the temperature of discharge by increasing that of the intake; and as it is not often desirable to exceed in the latter a temperature of about 1200° F. we are practically limited to about 170° for the discharge, and even from this we have to make an allowance for loss of heat by radiation, etc. If, with a fixed temperature of the intake, the temperature of discharge is too high, it probably indicates that the dryer is receiving more heat than it utilizes; if too low, that the degree of saturation is too high, and probably more heat could be introduced to advantage. No simple and easy rules can, however, be formulated on these points, and it is desirable occasionally to test the relative humidity at the different critical points. The saturation of the air to not exceeding 50 per cent., leaving still unexhausted one half of its capacity for vapor, will not materially impair its drying efficiency; and as we introduce into the apparatus the requisite heat, it will, if we properly dispose the material to be acted upon, do its appointed work of drying. It might be supposed that the recirculating system involved the moving of an undue volume of air; but when it is remembered that the introduction of the same amount of heat into the drying chamber at the same initial temperature would require the same volume of air if the external air were used to dilute the hot gases and the whole were directly discharged; but that in that case, as a larger portion of heat would escape with the discharged air unutilized, a greater total would be required, it will be seen that in fact the recirculating system calls for the movement of less air than that of direct discharge. For an evaporation of 25 pounds per minute, equal to 36,000 pounds of water per twenty-four hours, with a discharge at 172° half saturated, and the recirculation of five volumes, the air to be moved would be about 18,000 cubic feet per minute; within the capacity of a fan-blower of moderate size.

We have now to consider in what way the energies of heat and motion which we impart to the air, may be applied to the material to be dried advantageously and economically, as to space and otherwise, and not escape unutilized. According to the proverb, it is easy to bring the horse to water,

not always easy to make him drink. The laundress in drying her clothes hangs them on the line, if possible in the sun, but if there be a good wind blowing this is not essential; the haymaker spreads the grass and turns it occasionally, and by night his hay is made. But if the laundress, no matter how hot may be the air, leaves her clothes in a heap, or the haymaker his grass in the swathe, neither of them would dry; and the heat, instead of drying the clothes, would perhaps mildew them. If we take a hint from these simple natural methods of drying, we shall be likely to move in the right direction; and this brings us to the second requirement of successful drying, the method of handling the material. The problem is in fact how to spread our material and turn it over frequently, in contact with our drying currents. This is not without its difficulties, especially in the case of granular material, frequently of such low value when finished as to demand the utmost economy in all processes connected with its preparation.

The methods of handling textile fabrics are comparatively simple, and so well known as not to demand detailed description. Goods in pieces of considerable length are stretched from side to side or up and down in the drying chamber, in some cases moved automatically, and the drying currents have ready access to them. For articles requiring separate handling, as hats, etc., traveling shelves or their equivalent, carried on link belts or endless chains, are most successfully used, and may be moved either vertically or horizontally, according to the requirements of each case as to capacity and space available. Such articles are also to great extent simply placed in and removed from a drying room by hand. In handling material in lumps, powders or grains, the problem is less simple, and apart from revolving or fixed cylinders with stirrers, in which the heat is most commonly derived directly from radiating surfaces, not using air as its vehicle, there have been but few devices put into practical use.

For moving such material horizontally in a drying chamber using heated air, by far the most efficient and successful apparatus is that well-known one consisting of a series of superposed endless aprons, to which are given a slow motion, every alternate apron in opposite directions. The aprons being arranged stag-

gering, so as to slightly overlap each other at alternate opposite ends, the material fed in a thin layer upon the uppermost one of the series travels slowly forward and is deposited in succession upon each apron in turn, and finally delivered at the bottom, the currents of hot air having traversed its surface horizontally during its passage. These aprons are made of material suitable to the substance under treatment, and may, if desirable, be perforated, although this, in my opinion, adds little, if any, to their efficiency, as the air, which is sometimes introduced by apertures between the parts of each apron, will always follow the lines of least resistance, which will never be through a layer of the material to be dried, no matter how thin that may be. The aprons should have the greatest length practicable, in order to get a sufficient run, and may be of such width and construction as the weight and other qualities of the material to be treated indicate, by which considerations and that of the space available the number of aprons in a dryer is also controlled.

By the courtesy of the proprietors, I am allowed to give some details of apparatus on this plan, now in practical operation, which I have had opportunities of inspecting. One of them is in use for drying a chemical product which cannot be subjected without detriment to a high temperature. The aprons are eleven in number, spaced 16 inches apart vertically, and are each 50 feet long by 6 feet wide, giving a total length of 550 feet; they are moved at a speed of some 150 feet per hour, the material being thus retained in the drier between three and four hours. They are made of cotton cloth, and have to be occasionally replaced or removed and washed free of the incrustation which results from the deposition upon them of that portion of the salt in solution. The whole is enclosed in a tight wooden casing, and is supplied with air moved over steam coils by a fan blower. The air enters the dryer at about 195°, and is discharged at 135°. Its relative humidity at discharge is not measured, but from these figures cannot, even without allowance for heat radiated, etc., exceed 18 per cent. Obviously this is not economical of heat; but the material contains but a small percentage of water, and as exhaust steam is used, the cost of which is practically only that of the apparatus for conveying its heat into the air,

this is relatively of minor importance. The apparatus is considered, upon the whole, a satisfactory one, but by the introduction of a recirculatory system its economy, and probably its capacity, could be materially increased.

A dryer on this plan is also in operation in Brooklyn, N. Y., for drying brewers' grains, the spent malt from breweries. This material carries when wet from 75 to 80 per cent. of water. It constitutes when dry a food of high economical and commercial value for cows and horses; it is largely used as food for the former when wet, but as it is subject to very rapid fermentation and decomposition, and its use in this condition is highly injurious to the milk produced, and is by the laws of most States prohibited under heavy penalties, much of it produced in large cities is in summer thrown away. Owing to its great percentage of water, it is obvious that economy of heat in drying it is of the highest importance—is, in fact, imperative. It has been the object of many unsuccessful attempts. The apparatus in question is on a large scale, having a capacity of about 150 bushels of wet grain, equal to 2,000 pounds of dry, per hour, which would require for twenty-four hours' continuous working the evaporation of over 17,000 gallons of water. It consists of ten aprons, each 12 feet wide by 50 feet long, spaced about 24 inches apart, and contained in a substantial brick structure something under 30 feet high. A space of several feet is left clear of the aprons at each end of the casing, and adjoining one end, and of equal height, is the heat-generating furnace, having about 72 square feet of grate surface, and furnished with an independent discharge for the gases of combustion when not in use for drying. The large combustion and mixing chamber above the grates communicates by openings at different heights with one end of the drying chamber, and at or near the bottom of the opposite end the discharge is drawn by exhaust fans through two openings 30 inches in diameter. The aprons are of wire cloth, varying from 8 to 14 meshes to the inch, being graduated from the uppermost to the lowest apron in the series, and are carried upon transverse iron bars, which are attached at their ends to endless link belts. These are carried on sprocket wheels within the structure, and the shafts at one end of each

belt project through the brick wall, and are actuated by a link belt outside. The motion is at a speed of 6 to 8 feet per minute, giving from seventy-five to ninety minutes for the passage of the material, which is automatically fed upon the uppermost apron in a thin layer. The gases, tempered with air in the mixing chamber, are admitted to the dryer at a temperature which varies somewhat at the different openings, but does not exceed about 300°, above which it is undesirable to heat the grains. The discharge varies somewhat in temperature under different conditions of moisture of the grains and atmospheric conditions, but averages about 160° to 170°. This does not indicate a very high degree of saturation, but the apparatus has been for some time in practical operation, and is said to be drying grains with a relative economy of fuel greater than with any apparatus not first squeezing or wringing the grains, a proceeding which materially reduces the yield of dry grains, besides impairing their nutritive value.

But in a system moving material horizontally, certain unavoidable drawbacks are encountered. Among the most serious of these are: The difficulty of controlling horizontal currents of hot air, it being uniformly found in a chamber of considerable height and length that the current is mainly confined to the upper portion of the chamber, the material in the lower portion being scarcely acted upon. This difficulty increases with the height and length of the chamber, and can only, in part, be remedied by specially locating the positions of intake and discharge openings, or by admitting air of different temperatures at different heights in the chamber, both of which devices are the subject of patents; the influence of the wind, which, when in an adverse direction, has a tendency to drive the current back, causing great irregularity in the drying, and sometimes almost checking it; the amount of power absorbed in keeping in horizontal motion a considerable weight of material and apparatus; and, by no means the least important, where land is valuable, the large space on the ground occupied by horizontal dryers. In a vertical chamber or flue the tendency of an ascending current is to diffuse itself uniformly throughout its area, especially if in its course it encounters obstructions; if of considerable height, the

levity, or natural draft, of a heated column will materially assist its ascent; the direction of the wind will have little effect upon it; and it is obvious that such a chamber will occupy but a fraction of the space required for a horizontal chamber of equal capacity.

The desideratum for handling granular material vertically, is a device by which it shall be caused to descend by a regulated and methodical descent at such a rate as shall suffice for its drying, divided into small portions, frequently turned over, to allow of the ready access of the drying current. As the material will descend by its own weight, and as we shall only have to control or retard its descent, the power required to do this will be inconsiderable, and we shall at once attain the important economies of space occupied and cost of operation. The attempts to so handle material for drying with hot air have not been numerous, and I know of no apparatus at present in operation. I have devised and constructed, and have now nearly ready for operation, an apparatus in which I have attempted to embody the ideas which I have briefly set forth. The containing tower is of brick, enclosing a space on the ground of ten feet by twelve, and is eighty feet high, a considerable part of the height being utilized at the bottom for a receiving bin for the dried product, and at the top for the automatic feed bin. The drying chamber proper is something over forty feet high, and is provided with a large number (690) of receptacles for the material. These are eight feet long, and are cruciform in section, being formed of two strips of galvanized sheet-iron 7 inches wide, bent longitudinally in the middle to an angle of 90 degrees, and united at the angle by small knees or angles. Each receptacle thus forms four troughs around a common axis, of which two only will be active, the fourth limb of the cross, which separates and forms the two inactive troughs, serving only to deflect the air from a too direct course. These receptacles are disposed in 60 horizontal tiers, one above another, so arranged that those in each tier break joint, or alternate in position with those in the adjacent tiers above and below, and with suitable spaces for the passage of the air. The receptacles have at their ends cast-iron journals, and at one end cranks. The pins of the cranks are connected in one

system, so as to be simultaneously oscillated in either direction, or, if desired, rotated. The journals of the receptacles are carried on bearings formed in a structure of thin cast-iron plates, which is spaced some two feet from the brick wall of the tower, this space forming the return flue for the circulation of the air. Adjoining on this side is the furnace, connecting with this flue by valved openings. This flue is connected with the space in the drying chamber below the receptacles by a pipe leading through a 90-inch exhaust fan, by means of which the circulation will be maintained. The discharge opening is at the top, and may be, if necessary, put in connection with a smaller exhaust fan.

For many purposes the cruciform receptacle is most advantageous, while in some cases three limbs only and an angle greater than 90° would be preferable, and for materials corrosive or liable to be discolored by metals, a wooden construction would be substituted.

Supposing the dryer to be charged with material, each receptacle will have that one of its troughs filled which is at that time presented vertically. A simultaneous rotation through 90° will discharge the contents of each, which will be received in the troughs of the tiers below as they assume the vertical position, and the entire contents of the dryer will descend one step or stage, the contents of the lowest tier being discharged dry, and the uppermost being refilled with wet material by an automatic feed. After a suitable rest, determined by the rate at which drying proceeds, the tilting being repeated in the opposite direction, another descent will follow, and this will proceed continuously or until the material is exhausted.

The capacity of a dryer depends upon the length of time during which the particular material under treatment must be exposed; and this in turn primarily upon the amount of water to be eliminated, but almost equally upon the degree of facility with which the material will give up its moisture; as to which there are wide differences. Thus, if you place on your table pieces of clay and of soap of equal weights and equally charged with moisture, in a few days the clay will have become so dry that you can crumble it to dust and blow it away with your breath; in as many months the soap will still retain a large part

of its original water. It is not, therefore, possible to estimate closely the capacity of any dryer on the basis only of the percentage of moisture in the material; the most we can do is to judge by experience with nearly similar substances; and it is always prudent to allow a large factor of safety. In this apparatus, there being sixty tiers, an oscillation at intervals of one minute would allow one hour for the passage of the material, and this would vary as the intervals of tilting were increased or diminished. The small portions into which the material is divided, and the large and frequently renewed surface constantly exposed for the escape of the vapor will greatly facilitate evaporation. The entire heat generated by the combustion being introduced into the dryer, the loss by radiation being greatly reduced by carrying the return flue within the external walls, and that of the air of discharge by this use of the recirculatory method, economy of fuel will result. The space occupied on the ground is small, the power required for its operation inconsiderable; and I have thus attempted to combine and assemble the requisites which in the first part of this paper I stated as essential to a successful and economical hot air dryer.

It is obvious that it is entirely practicable in a dryer of this construction, where a smokeless fuel is used for making steam or other purposes, to employ the waste gases from the stack for drying instead of burning fuel in a separate furnace; and it is contemplated to so use them in breweries for drying the grains. In such use, as the gases would already have parted with much of their heat, they would enter the dryer at a comparatively low temperature, possibly below 500°; and we have seen that a corresponding decrease of the temperature of discharge must follow, with its resulting loss of heat. But in this case as the heat which would be utilized would otherwise be entirely wasted, we can well afford to accept this loss. An exhaust fan at the discharge would prevent any retardation of the draught, or might if desirable be regulated to increase it. If in any case the waste gases were not sufficient for the requirements, it would be practicable to supplement them by an auxiliary furnace, and in this case, as the temperature of the intake would be raised, the temperature of the discharge would also rise, and a still larger proportion of the value of the waste gases employed would thus be realized.

XI.

THE FIRST UNITED STATES PNEUMATIC POSTAL SYSTEM.

By A. Falkenau, Active Member of the Club.

Read, April 21, 1894.

The year of trial of the first pneumatic system for postal service in the United States, as installed by the Pneumatic Transit Co. of New Jersey, has been completed to the satisfaction of all concerned, and the question of extending the system for commercial as well as postal service is now agitated. The subject is, therefore, one of timely interest, and the success of the novel engineering features warrants its presentation here to-night.

The building of the Philadelphia plant involved peculiar problems, due to the departure from European practice, which are of special interest. Before entering upon the consideration of the Philadelphia plant it may be well to give a brief review of what has been done in London, Paris and other European cities. Pneumatic railways need not be considered, and I will confine myself solely to that system of pneumatic transmission in which the carrier does not rest on wheels, but is supported by the packing between it and the tube, and for want of a better name might be called the cartridge system.

Pneumatic transmission of this kind is used quite extensively in Europe for the delivery of special messages akin to the telegraph service. None of the tubes, however, are large enough to permit the transmission of regular mail matter. The earliest experiments with pneumatic transmission were made in 1852 at Ador, near Paris, but the first pneumatic tubes to be put to practical application were introduced by Mr. Latimer Clark of the London Telegraph Co., in 1854. Siemens & Halske installed the first system in Berlin in 1865. In 1866 French engineers installed a similar system in Paris. Since that time systems have been established in Liverpool, Manchester, Vienna, Brussels and elsewhere. Clark's first line was established between two departments of the main telegraph office in London. The tube was a

leaden one, three-quarters of an inch in diameter. Each end of the tube could be connected with a vacuum reservoir or left open to the outer air. When it was desired to send a carrier, a signal was first given by an ordinary speaking-tube whistle. The attendant at the receiving end connected the dispatch tube to the vacuum reservoir, the other end being open to the air, thus creating an air current to propel the carrier. When the system was extended to greater distances, the vacuum pumps being situated in the central telegraph office, carriers from outlying offices could be propelled to the main office, but could not be sent back through the tubes.

At one time a vacuum reservoir was located at a distant station and exhausted from the central station, by means of a small separate pipe, thus furnishing a means for propelling carriers to the sub-station. This did not prove satisfactory and was therefore soon abandoned. In 1866 Mr. C. F. Varley introduced the use of compressed air for sending messages to outlying stations, which method has been in use ever since. One important modification, however, has been made. In the early system a single tube was used between stations. Now two tubes are used and the currents can be kept in constant action, where the volume of business requires it. The tubes used in London are 1½, 2¼ and 3 inches in diameter and are leaden pipes, laid inside of cast-iron ones, with the exception of the first installment of 4,116 yards of 3-inch pipe, which is of wrought iron. In the case of new extensions 2¼-inch leaden tubes are now invariably laid. The method of making the joints is shown in Fig. I. The tubes are made in lengths of about 29 feet, squared at the ends. A steel mandril attached to a chain is drawn through the pipe to make it smooth, cylindrical and uniform throughout, and also serves to center the two abutting ends, while a plumber's wiped joint is being made. The iron pipes are drawn over the leaden pipe, leaving enough of the end of the pipe exposed to make the next plumber's joint. The illustration shows the cast-iron pipe not yet in its final position. Sections of leaden pipe when examined after twenty years of constant use showed but little wear and were very smooth. London authorities prefer the leaden pipe, while in Paris, Berlin and Vienna wrought-iron pipes are exclusively used. The difficulties expe-

rienced from rust in London were probably due to the use of an air compressor employing injected water. This has, however, been out of service a long time, but is no doubt largely responsible for the prejudice in favor of leaden pipe. In the continental systems where wrought-iron pipes are exclusively used, traps with drain cocks are located at various points along the line.

The $2\frac{1}{2}$-inch tubes in Paris are drawn wrought-iron ones, the joints being made with male and female flange unions, while in the Berlin system, where the wrought tubes are $2\frac{1}{2}$ and 3 inches in

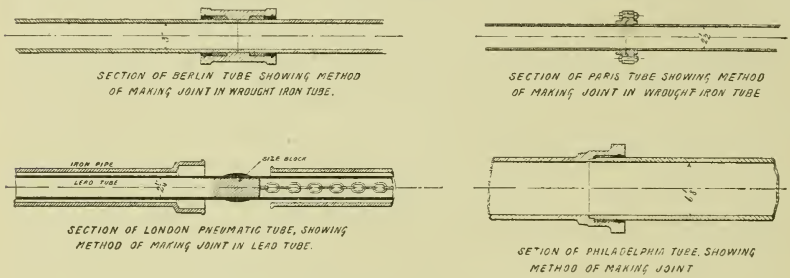


Fig. I.—Tubes Used in Four Cities.

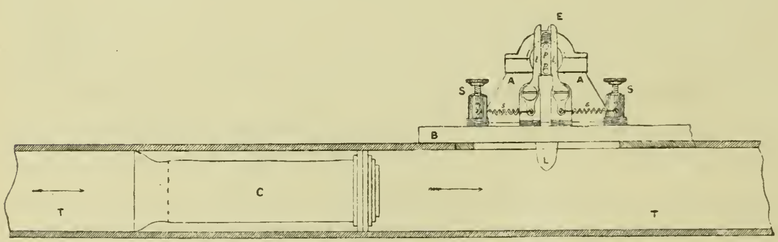


Fig. II.—Carrier and Electrical Signal Apparatus, London.

diameter, the joints are made with a bored sleeve, provided with recesses at each end, for the insertion of oakum and lead caulking. The various joints and the relative sizes of tubes used in the cities mentioned are shown in Fig. I.

The carrier used in London is shown in Fig. II. It consists of a cylindrical gutta-percha tube covered with felt, which extends beyond the rear open end of the carrier forming a skirt, which serves as a packing ring. The pressure behind this part causes it to expand until it exactly fits the tube. The front of the carrier is provided with a felt piston, which also serves as a

buffer. An elastic band across the rear opening can be stretched sufficiently to allow messages to be put in and serves to retain them in the carrier. The length over all of a carrier for a $2\frac{1}{4}$-

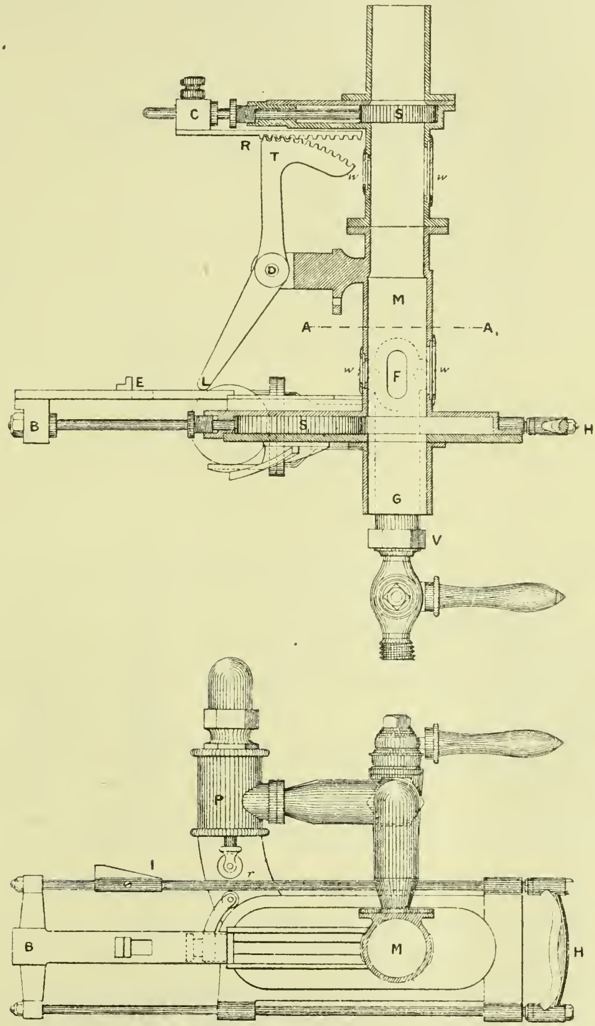


Fig. III.—Receiver and Transmitter, London.

inch tube is $6\frac{3}{4}$ inches. The inside measurement of the gutta-percha tube being $4\frac{3}{4}$ inches in length and $1\frac{1}{4}$ inches diameter. The weight of such a carrier when empty is a little over 3 ounces,

and the weight of the 12 or 14 messages which can be sent is less than 2 ounces more, making the total weight of a loaded carrier not over 5 ounces. The illustration shows the carrier just as it is about to strike the lever *L* of a block-signaling apparatus, such direct impact being permissible, a point deserving notice, as will be shown later on. The tubes are worked like a line of railway, the block system of signaling being used in order to insure that no two carriers should occupy the same section of a tube at the same time.

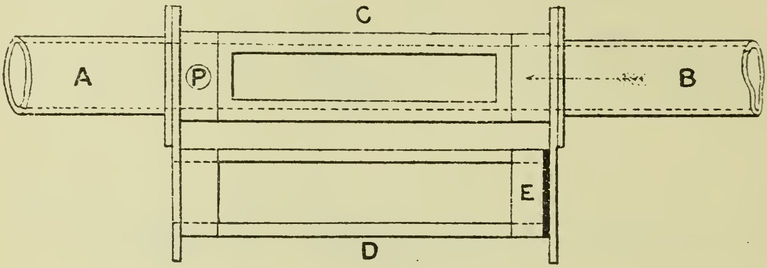


FIG. IV.

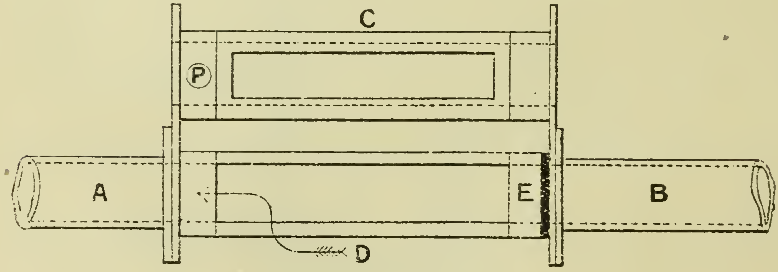
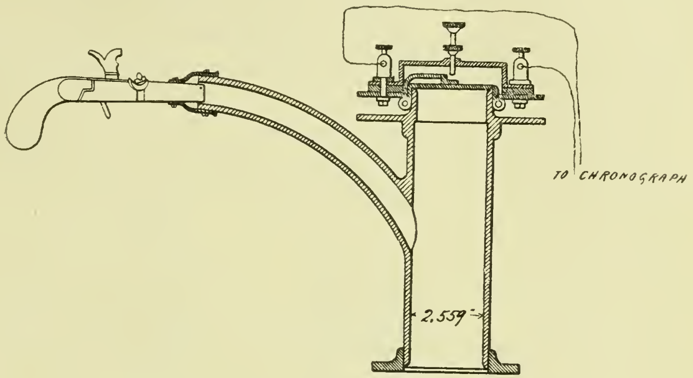


FIG. V.—INTERMEDIATE SWITCHES.

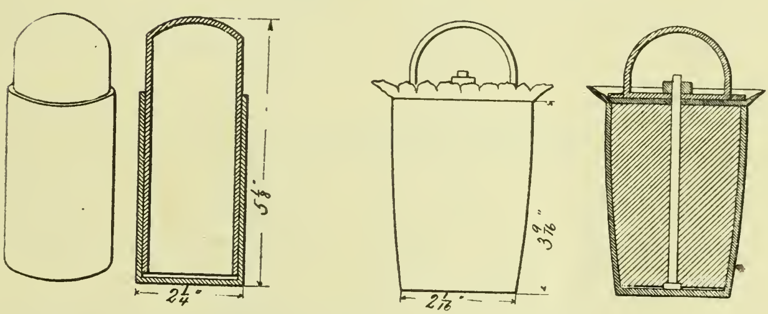
Fig. III, shows the Wilmot Double Sluice Valve, which is the dispatching and receiving apparatus generally used, although it is now gradually being replaced by a simpler apparatus known as the *D* box. The gates S & S_1 are operated through the handle *H* and as will be readily seen are so connected that both cannot be open at the same time, the lower gate S_1 being twice as long as the upper one *S*. Through the opening *F* the air current is established either by compressed air or vacuum, as desired. In

sending a carrier it is inserted at *G*. In receiving a carrier it strikes directly on the gate S_1.

Where there are intermediate offices on a vacuum tube the intermediate switch shown in Figs. IV and V is used. It consists essentially of two short sections of tube *C* and *D* mounted



APPARATUS FOR LOCATING OBSTRUCTIONS



SOME APPLIANCES – PARIS SYSTEM.

FIG. VI.

on a rocking frame, so that either may be made to form part of the main tube *A B* at will. With *C*, which is furnished with a sealed glass cover, in position as in Fig. IV, the tube *A B* forms a continuous channel for the air, and all carriers coming from *B*

are stopped by a brass pin *P*, which projects down into the tube. If the attendant at the intermediate office does not wish to remove the carrier he raises the pin and allows the carrier to proceed. Otherwise he sets his switch over to the position as shown in Fig. V and takes out the carrier. The section of tube *D* has an aperture along its length for the insertion of carriers, and is permanently closed at *E*, so that the vacuum in pipe *A* now draws in the air from the intermediate office, as indicated by the arrow.

A point worthy of special attention, as will be shown later on, is that in the three apparatuses just described, direct impact between the carrier and some part of the apparatus is evidently not at all objectionable.

The Paris carriers, as shown in Fig. VI, are made of sheet-iron, and a leather case serves at the same time as a cover, to give a wearing or protecting surface and to close the open end of the iron box. These carriers are $2\frac{1}{4}$ inches internal diameter and 5 inches long, utilizing proportionately a greater part of the diameter of the air tube for message room than the London carriers. The weight of the Paris carriers is eight and three-quarter ounces. These carriers are propelled through the tubes by a wooden piston with leather packing, which weighs twelve ounces.

In the London system each carrier is passed through the tube singly, while in the Paris and Vienna systems the wooden piston propels a train of as many as ten cases, such a train weighing about nine pounds. These trains are dispatched at intervals of about fifteen minutes. Such a train is shown in Fig. VII just arriving at the station.

The London carriers last for about 2,000 miles of travel, while the Paris carriers last but 1,200 miles.

In the London system very little trouble has been experienced from the carriers sticking in the pipes, while in Paris there appears to have been more annoyance from this source.

For locating the obstruction very ingenious means are used. Part of the apparatus employed is shown in Fig. VI. A pistol being discharged into the tube, the sound acts on a diaphragm, which closes an electric circuit, thereby producing a mark on a

chronograph. The sound-wave meeting with the obstruction is reflected, and on its return to the diaphragm a second mark is recorded. From the interval of time thus determined the location of the obstruction can be calculated.

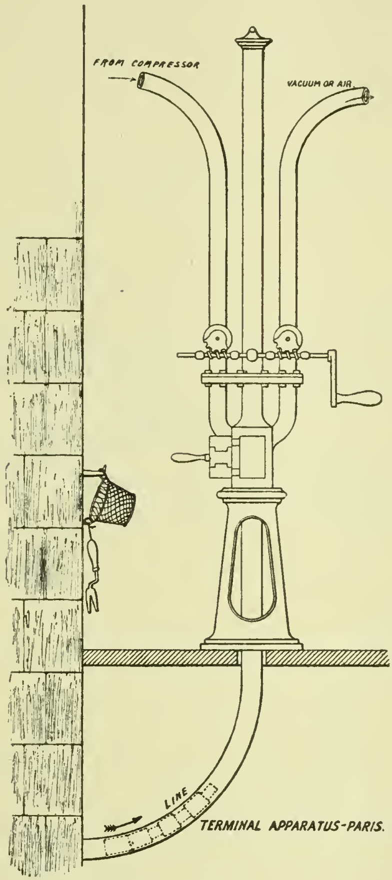


FIG. VII.

From the records covering a series of years it was found that obstructions due to the wedging of carriers averaged eight per annum. Among the causes to which these accidents were ascribed were the opening of the boxes and scattering of the dispatches through the tube; the breaking of the piston, parts

of which became wedged, and also the wrinkling of the leather covering of the carrier.

The valves at the terminals in the European systems can be comparatively simple, owing to the small diameter of the tubes used and the consequently light weight of the carriers. In the Paris terminal apparatus the carriers are cushioned by air and the tube closed at one end, while in the London terminals the carriers are allowed to strike the valves, the blow being but a slight one.

There are two systems of laying the tube lines in use, the radial and the circuit. In the radial system, as the name implies, the

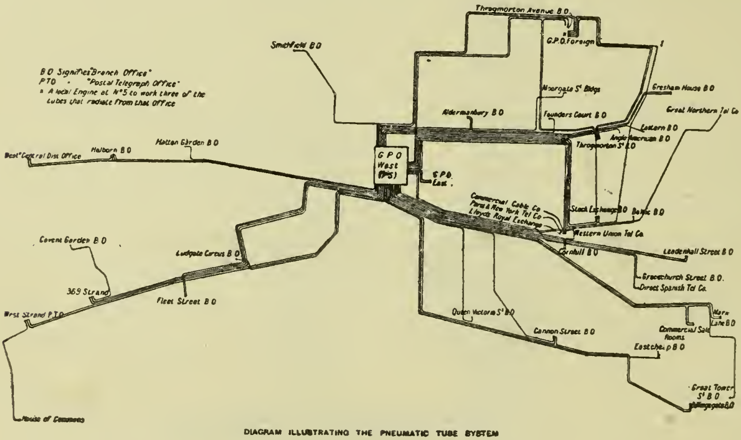


Fig. VIII.—Radial System.

pipes radiate from the central to the sub-stations. This is clearly illustrated in Fig. VIII, showing the London system, where the General Post Office is the central station from which both outgoing and return tubes are laid to most of the outlying stations. At the smaller stations traffic is carried on through one tube only. In the circuit system a single pipe starts from the central station, and after making a circuit through a number of outlying stations returns to the starting point. This will be readily understood by inspecting Fig. IX, a diagram of part of the Paris system.

There has been some contention as to which of these systems

is the best. In London the radial system has always been used, while Paris and Vienna employ the circuit system. The latter was originally used in Berlin also, but was replaced by the radial system in 1884.

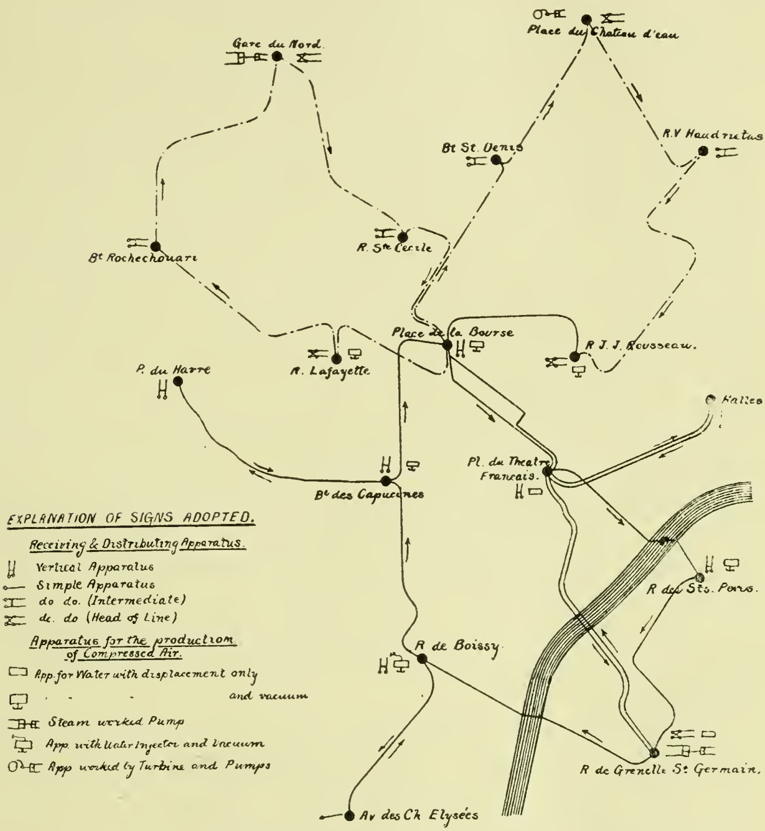


DIAGRAM OF PART OF PARIS PNEUMATIC TUBE SYSTEM.

Fig. IX.—Circuit System.

In Fig. IX three circuits are shown centering in the Place de la Bourse. Two lines, with up-and-down tubes, radiate from Place du Théâtre Français to Halles and Rue de Grenelle. Again, single lines of pipe, through which up-and-down traffic

is carried on, are shown at Place du Havre and Avenue des Champs Elysées, so that in reality the Paris system is a combination of the circuit and radial systems.

In the original plant, city water was largely used for producing compressed air and vacuum by various methods, as will be seen from the notes accompanying Fig. IX. In 1872, however, the water compressors were replaced by steam-power plants.

Two of the stations, with power plants, are shown in Fig. X. The station shown in the upper view is provided with the vertical receiving and transmitting apparatus shown more fully in Fig. VII. The train is projected into the vertical central tube, which is closed at the top, forming an air cushion. The attendant takes the fork shown hanging on the wall, and placing its prongs across the tube through the door shown at the foot of the cushion tube, catches the train as it rebounds. In dispatching a train, he first drops the carriers into the tube and then the piston, closes the door and then turns the crank shown, whereby the valve in the pipe on the right, communicating with the outer atmosphere, is closed, and the valve in the pipe on the left is opened, admitting compressed air. The lower view in Fig. X shows a horizontal apparatus of somewhat similar construction.

The main pumping station at the London General Post Office is shown in Fig. XI. The valves near the pumping cylinders are so arranged that the pumps may produce compressed air or a vacuum, as desired. There is another small pumping station at Throgmorton Avenue.

The magnitude of the European plants may be gathered from the following statements. The London system has 42 stations and a total length of 34 miles of tubes. There are six engines of an aggregrate of 216 horse-power, of which 158 are in constant demand. The average number of messages transmitted daily is 56,800. Liverpool has five miles of tubing, using 60 horse-powert Berlin has over 28 miles of tube line with 38 stations and eight steam engines aggregating only 128 horse-power.

From what has been said it is apparent that the great convenience of and practical facilities for working small tubes have been amply proved as adjuncts to the telegraph service in Europe. It is, however, only within recent years that in this country the first

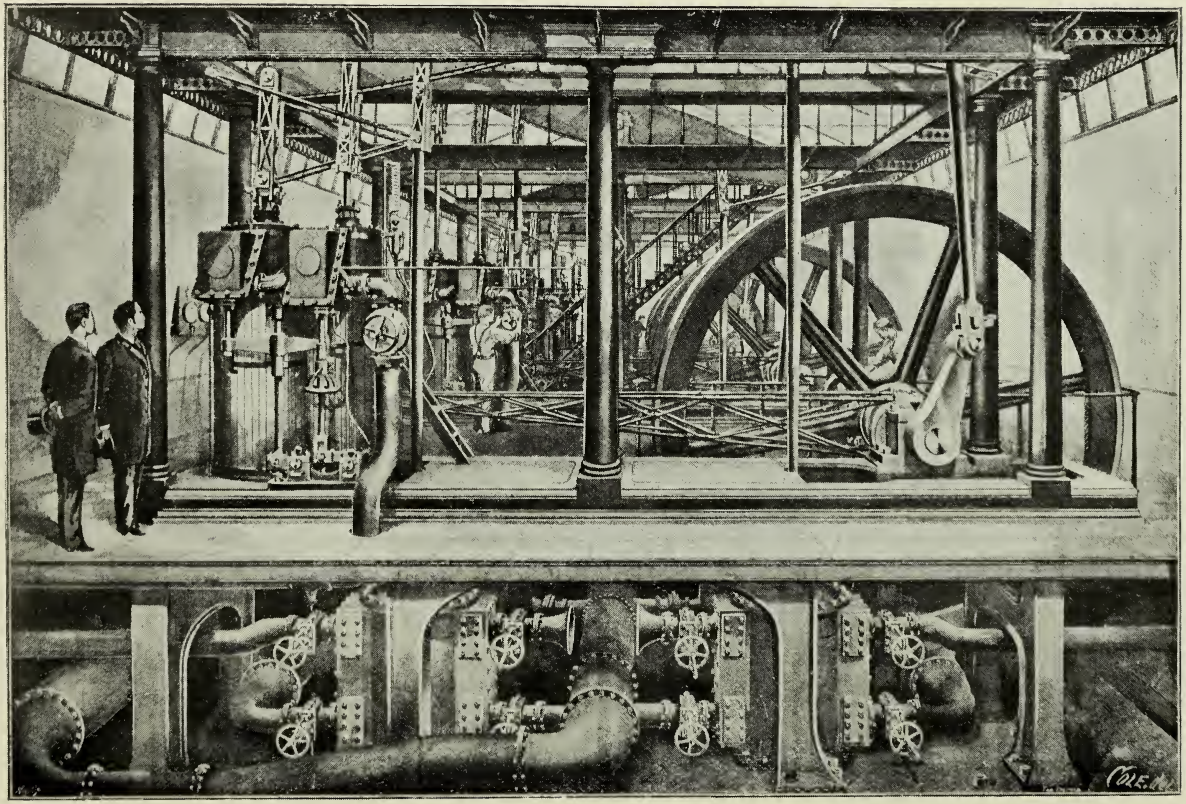


Fig. XI.—Main Pumping Station, London.

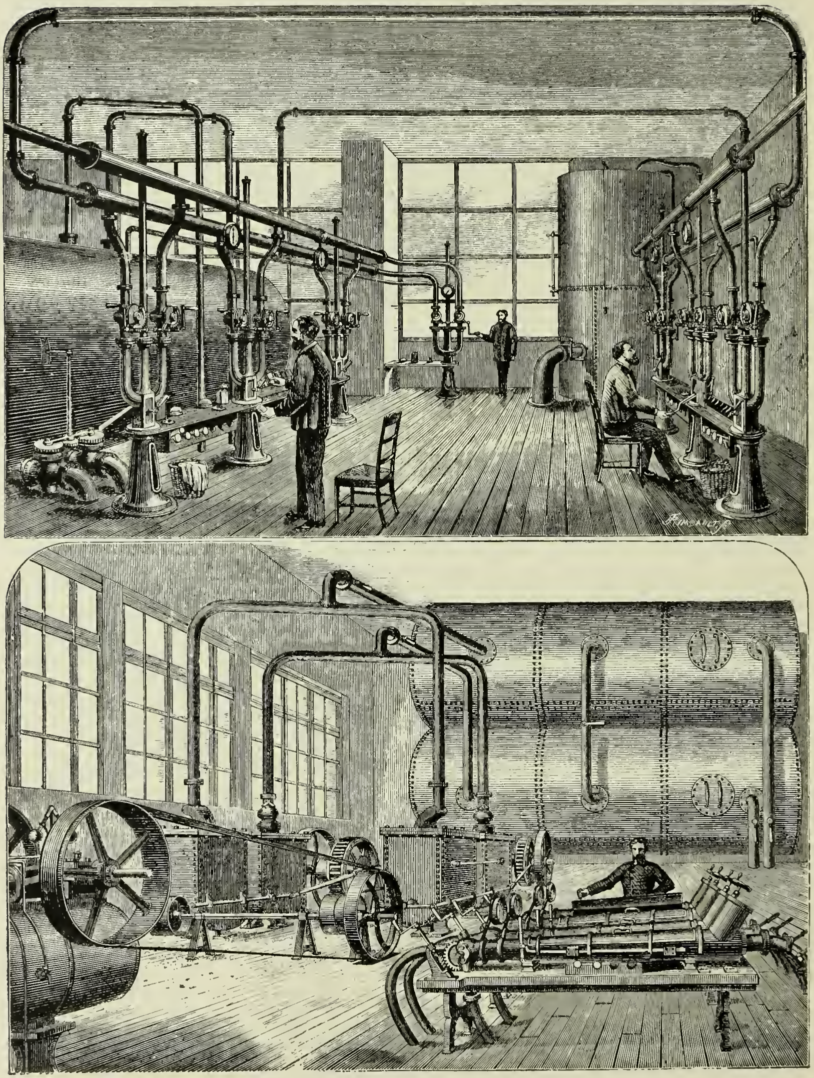


Fig. X.—Stations on Paris System.

extended use of the pneumatic system was made by the Western Union Telegraph Company, which now has tubes from 2 to $2\frac{1}{2}$ inches diameter in several of the larger cities.

It was not till 1892 that the United States Post Office Department decided to make the experiment of using pneumatic transmission, and accepted the proposition of the Pneumatic Transit Company, of New Jersey, to install a plant under its system in Philadelphia and operate the same for one year free of expense to the Government. This plant has been built and was formally put into service February 17, 1893, and has been in successful operation ever since. The tubes, which are $6\frac{1}{8}$ inches in diameter, are much larger than any heretofore used, and this feature

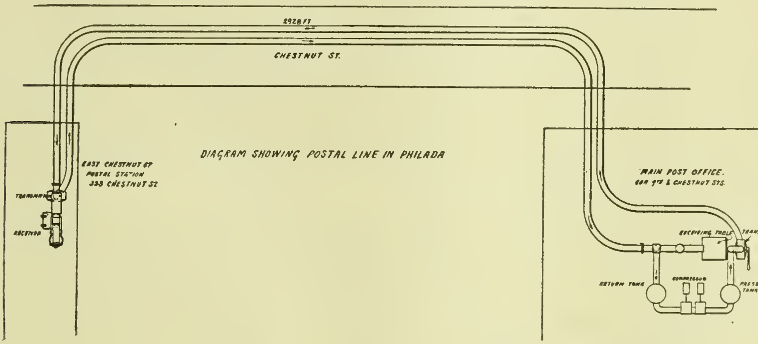


Fig. XII.

has introduced various problems which Mr. B. C. Batcheller, the engineer of the company, has solved in a very original manner. In the European systems the carriers are so light, weighing only a few ounces, that direct impact with a fixed object does not result in any serious consequences, but the carriers here used, which will contain 150 to 200 letters, weigh loaded 12 to 14 pounds, and blows must be avoided.

The Philadelphia plant, as shown in Fig. XII, is operated between the main post-office at Ninth and Chestnut Streets, and the sub-station on Chestnut Street between Third and Fourth Streets, a distance of 2,928 feet. As there are two tubes, one leading to and one returning from the sub-station, the total length of the tube is 5,856 feet.

The straight portions are cast iron and the bends are made of brass with a six foot radius. The cast-iron pipes are ordinary water-pipes bored to $6\frac{1}{8}$ inches in diameter, the joints being made in the usual manner with oakum and lead caulking, as shown in Fig. I. To insure alignment the bell ends are counterbored half an inch in depth and $6\frac{3}{4}$ inches in diameter, while the spigot ends are turned down to fit this counterbore. Where the iron and brass pipes are united male and female flange unions are used.

The pipes are laid about four feet under the surface of the street, but in order to pass under the network of pipes and conduits encountered at street crossings, it was necessary in places to reach a depth of as much as thirteen feet, and the pipe follows grades of as much as six feet in a hundred.

In the basement of the main post-office is located a Clayton duplex air compressor, with steam cylinders bored ten inches in diameter and air cylinders of eighteen inches bore. The stroke of the pistons is twenty-four inches. Thirty horse-power is developed by the engines in maintaining the air at seven pounds pressure as required at present.

The air is forced into a tank where any moisture is drained off and then passes through the transmitting apparatus into the outgoing line of pipe. This terminates at the sub-station in the receiving apparatus, which is normally closed to the atmosphere. At a point in the pipe just anterior to this apparatus, a branch is taken off diverting the air through the transmitter of the substation and thence into the return pipe. This terminates in the receiving apparatus at the main post-office. A gate valve in the latter being normally closed, diverts the air through a branch pipe which enters a tank from which the compressor draws its air. This tank has a small opening communicating with the atmosphere, thus permitting the compressor to supply any loss from leakage. It will thus be seen that the same air is constantly circulated through the system of pipes.

The transmitter shown in Fig. XIII and which can also be seen in Figs. XIV, XV, XVI, XVII and XVIII is practically a straight way cock with a hole in the side of the shell so located that the cock can be turned to permit the insertion of a carrier. The cock being turned back to the straight way position the air

current propels the carrier through the tube. This apparatus is so constructed that the flow of air through the pipe is not obstructed when in position to receive a carrier, the width of the case being greater than the diameter of the movable piece of pipe within it.

The transmitters in both stations are alike and easily operated by hand. A time lock is provided so that carriers cannot be sent at too close intervals. At present a carrier can be sent every ten seconds, but this time can be shortened if desired.

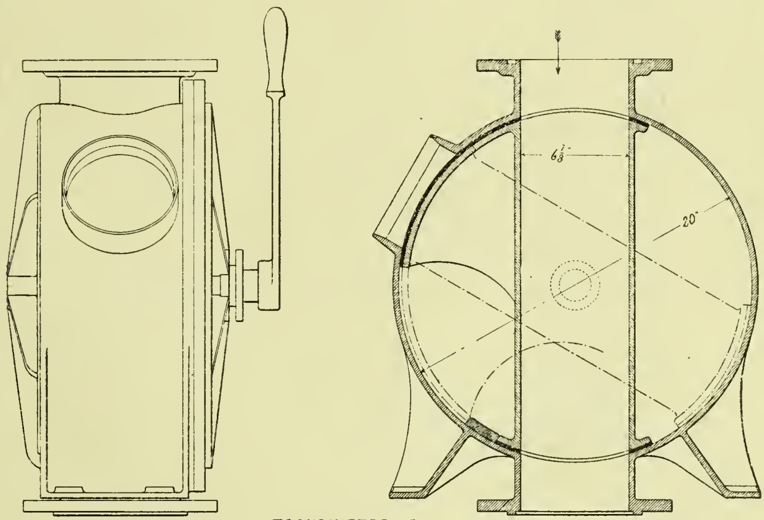
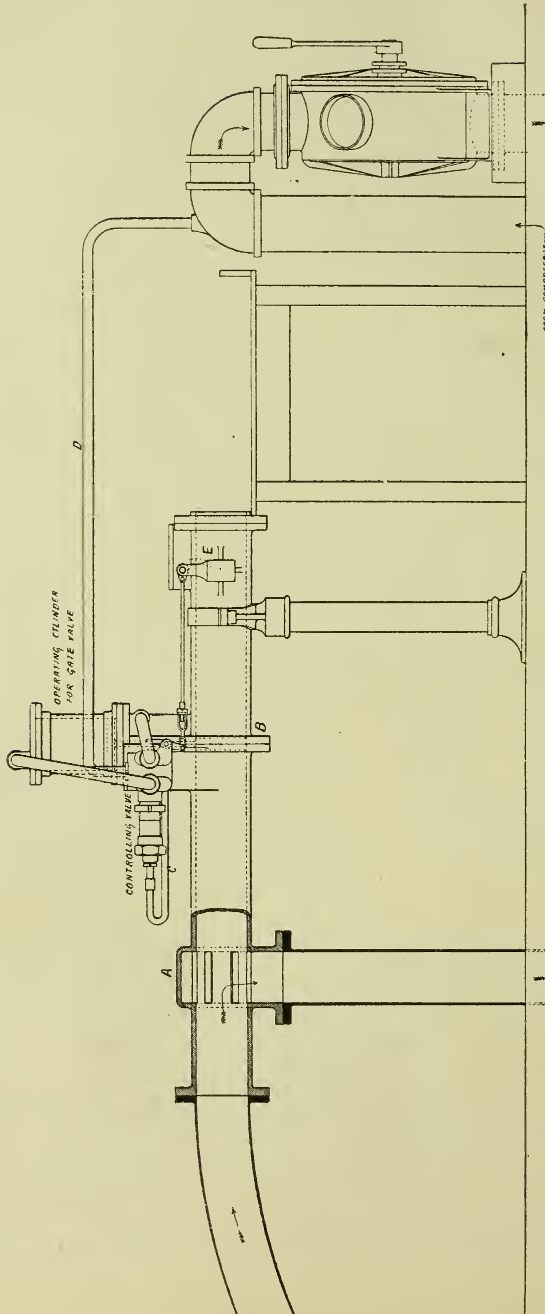


Fig. XIII.

When a carrier enters the receiving apparatus its momentum is very great, and Mr. Batcheller has ingeniously arranged an air cushion, which at the same time serves the purpose of operating the mechanism for discharging the carrier into the atmosphere, thus making the apparatus entirely automatic.

The receiving apparatus at the main post-office shown in Figs. XIV and XVI is practically a continuation of the line pipe with its end open, permitting a carrier to be discharged directly on to a table. The gate valve near the end of the apparatus is opened and closed by the action of the carrier. The carrier, after passing



APPARATUS AT MAIN OFFICE - PHILA

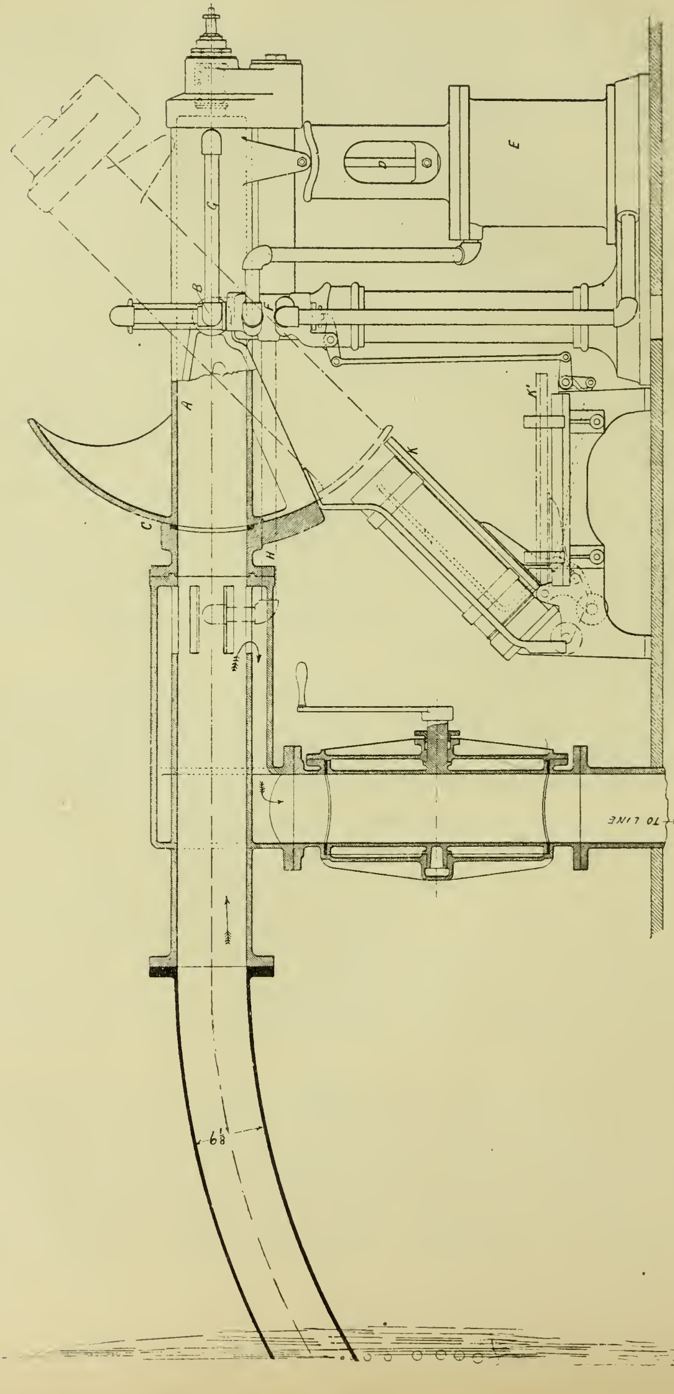
FIG. XIV.

point *A*, compresses the air between it and the gate valve *B*. This compressed air passing through pipe *C* throws the controlling valve, which then admits compressed air from pipe *D* under the piston of the operating cylinder, thus opening the gate valve. The velocity of the carrier is at the same time effectually checked and the latter comes to a stop just in front of the gate. When this is open the slight pressure of the air in the pipe is merely sufficient to eject the carrier, depositing it on the table at the mouth of the apparatus. In passing out it strikes the toe *E*, which effects the closing of the gate valve. It should be noted that the pressure of air at point *A* is very nearly that of the atmosphere, so that when a carrier is checked after passing that point only a small amount of new energy can be imparted to it.

The receiving apparatus at the sub-station shown in Fig. XV and views Figs. XVII and XVIII consists of a tube *A*, closed at the back end, mounted on trunions at the point *B*, similar to a cannon. The open end of the receiver matches the end of the incoming tube at the joint *C*. To the back end of the receiver is attached a rod *D*, connecting it to a piston, running in the operating cylinder *E*, located below it.

A carrier entering the tube *A*, compresses the air between itself and the end of the tube, driving part of it through the pipe *G*, and actuating the controlling valve *F*. In this way compressed air from the pipe *H*, is admitted under the piston of the operating cylinder, which then rises and tilts the receiver to the position shown in the drawing by broken lines. The carrier falls out by gravity on to a lever *K*, which, actuated by the weight of the former, moves to position *K'*, thereby reversing the controlling valve of the cylinder, so that the piston moves down again and returns the receiver to its original position. This automatic apparatus has worked regularly two or three hundred times a day since its installment.

The air pressure at the compressor is seven pounds and at the sub-station is somewhat less than four pounds. The fact that the pressure at the sub-station is greater than one-half of seven pounds is explained by certain theoretical considerations which I hope to present at some future time. When a carrier arrives at this point the checking of its momentum compresses the air to about twenty-



APPARATUS AT SUB-STATION - PHILA.

Fig. XV.

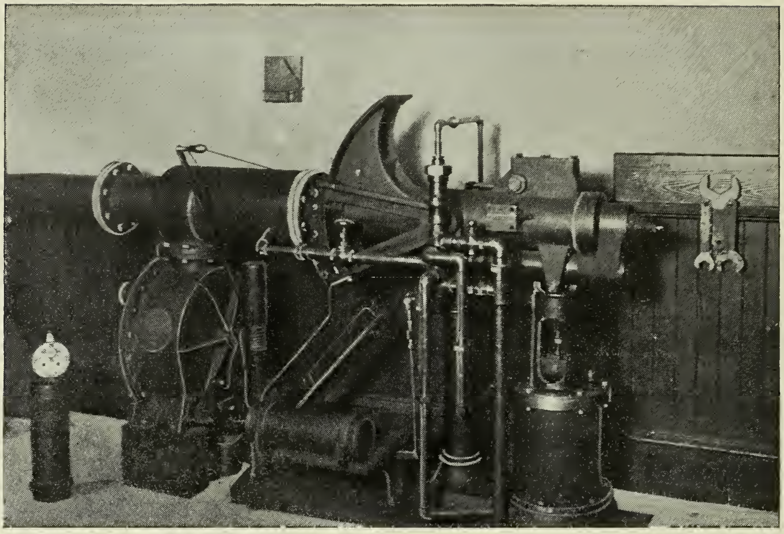


FIG. XVII.—VIEW OF APPARATUS AT SUB-STATION, PHILADELPHIA.
RECEIVER CLOSED.

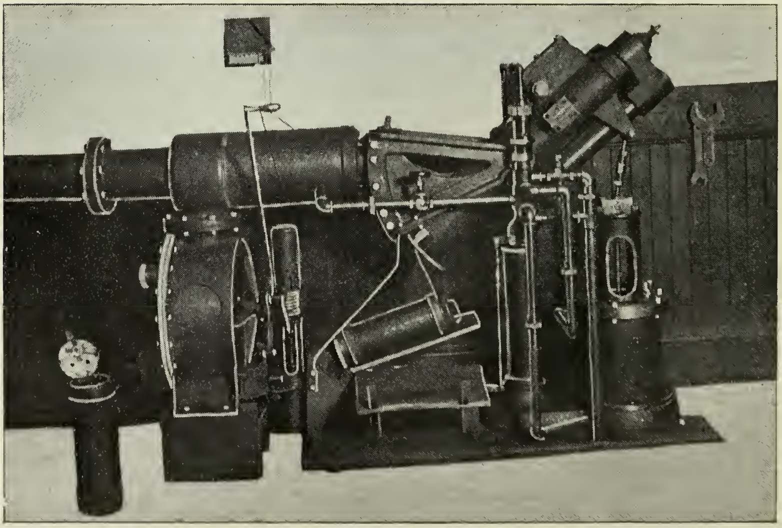


FIG. XVIII.—VIEW OF APPARATUS AT SUB-STATION, PHILADELPHIA.
RECEIVER OPEN.

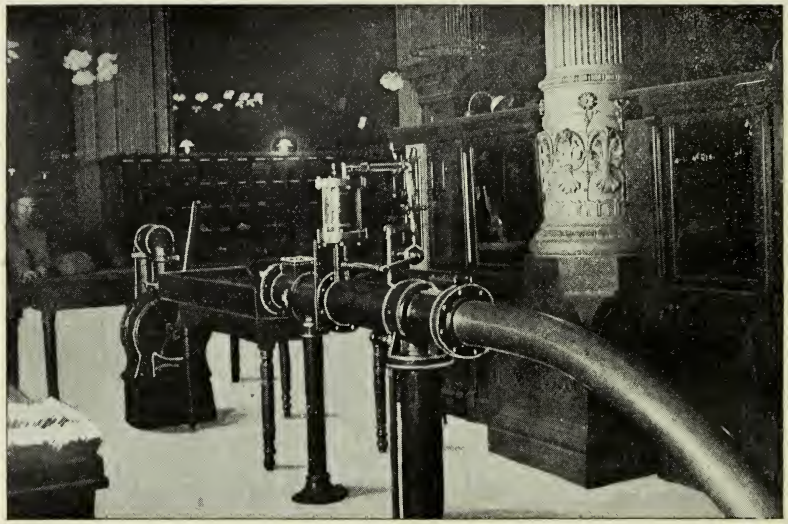
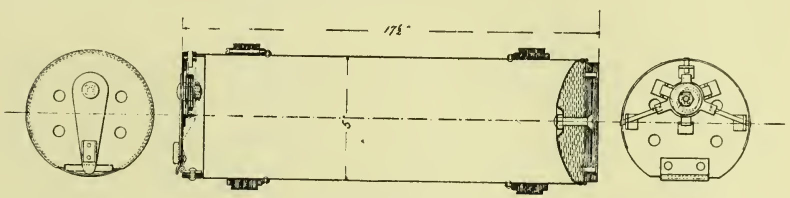


Fig. XVI.—View of Apparatus at Main Office, Philadelphia.

eight pounds, thus supplying a pressure which operates the valves reliably and promptly. This action is quite satisfactory until the carrier packing has been reduced by wear three thirty-seconds of an inch in diameter. The carriers shown in Fig. XIX are $5\frac{1}{4}$ inches in diameter and 18 inches long with packings near both ends $6\frac{3}{32}$ inches diameter. They are made of steel, weigh $9\frac{1}{2}$ pounds and are provided with buffers at the front end. The mouth of the carrier is closed by a lid, locked in such a way that it is impossible for it to open while in the tube. The packings were first made of felt, but canvas has been found superior in its wearing qualities. The packings will last about 550 miles or one-fourth the life of the small carriers used in London. There has been but little indication of rusting of the pipes, and moisture is apparent only for a short time after starting up the plant.



MAIL CARRIER.-PHILA.

FIG. XIX.

The trip from the main post-office to the sub-station is made in sixty seconds and the return trip in fifty-five seconds, or with velocities respectively at 48 and 53 feet per second. The average speed used in European systems is about the same, being thirty miles per hour.

Taking the same velocities, say 50 feet per second, the stored energy $\frac{mv^2}{2}$ in a London carrier wolud be about 12 foot-pounds, while in the ordinary Philadelphia carrier it is 500 foot-pounds. In one instance, at election time, when some stereotypes making a total load of 37 pounds were sent in haste, it rose to 1,436 foot-pounds. The seriousness of the problem of dealing with such energy and avoiding blows must be apparent. In this connection I may mention that the first receiving apparatus at the sub-station was similar in general principle to that at the

main post-office. It was provided with a light hickory stick which the carrier swung out of its path and which served to deflect its course when it rebounded, from an air cushion located two feet beyond. Although the stored energy at the time of striking the light stick was far less than that in its course through the pneumatic tubes, the carriers were injured and in consequence of this and the noise accompanying the discharge of the carrier, the new apparatus was designed.

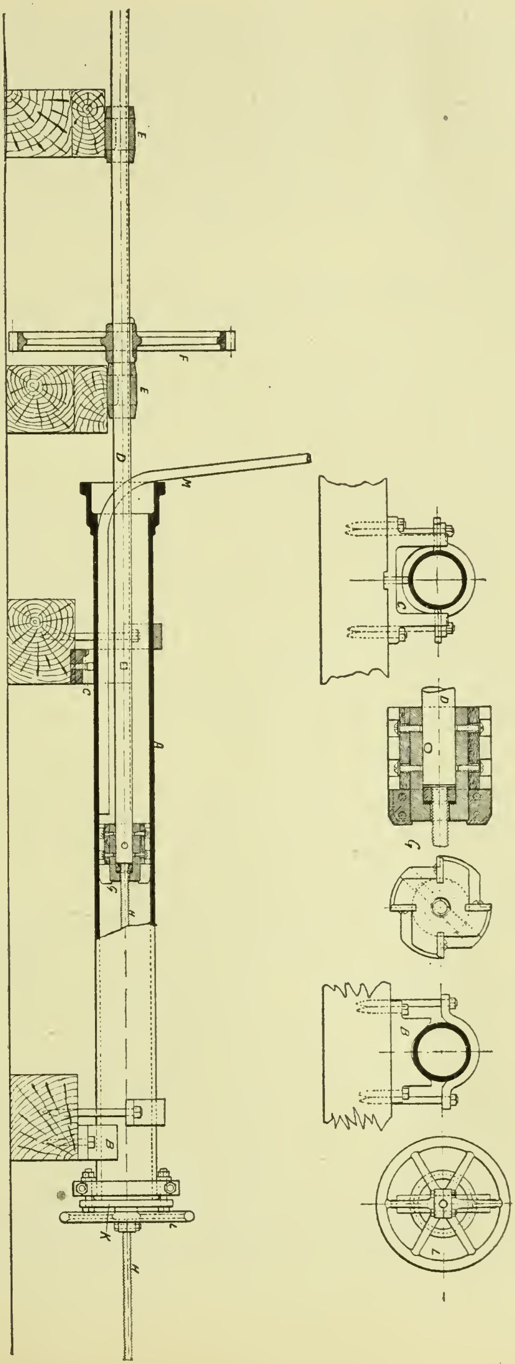
So far there has not been a single case of a carrier getting wedged in any part of the tube, so that no means for determining the location of obstructions have been called into requisition. The only accident to the pipe thus far recorded was the cracking of one near the Continental Hotel.

In the course of constructing the Philadelphia system various difficulties were encountered in the street work and in carrying out the mechanical details.

It was originally intended to use wrought-iron pipe, but when this was ready for delivery, it was found to vary so much in diameter, that it had to be rejected. As time was of importance Mr. Batcheller thereupon proposed to use bored cast-iron water-pipe, but met with so little encouragement from concerns equipped with proper boring machines, that I was led to devise a method of doing the work, which was a radical departure from the usual ones employed and which proved entirely successful, twelve machines being built and 6,500 feet of 6-inch pipe bored, between November 8th and December 31st, 1892.

Realizing that the pipes did not need te be absolutely straight as long as the bore was uniform and continuous, I concluded that the ordinary form of boring machines with rigid bar was not needed, and that great advantages were to be gained by reaming the pipes with a flexible reamer, and for this purpose built twelve crude machines within a short time and started boring pipe within a week of taking the contract. Some of the new features introduced were the pulling of the reamer through, instead of pushing it, and the use of air for the double purpose of blowing out the chips and keeping cutters cool.

My intention was to use air at a high pressure, which would have a great cooling effect due to its expansion. Under the press-



PIPE BORING APPARATUS.

FIG. XX.

ing circumstances we had to content ourselves with a Sturtevant blower, but even from that the air current gave good results. We had thermometers attached to the pipes, but unfortunately these were broken as fast as we supplied them, and the unreliable results we obtained were that the cooling effect in individual pipes was from 20 to 60 degrees, while the lowest reading of the thermometer with the blast on was 120° F., and the highest with blast off 210° F.

The material in the pipes varied very much and the temperatures necessarily with it. In using air, however, we introduced what proved a serious trouble for our neighbors. The graphitic carbon was winnowed from the iron dust and permeated the air for the entire block, destroying valuable bindings in a bookbindery and tape in a button factory.

There were 544 pipes bored in all. They were ordinary 6-inch water-pipes in lengths of twelve feet. A limit of one thirty-second of an inch above or below the standard bore of six and one-eighth inches was set. All pipes were tested by limit gauges. 4 per cent. of the total lot were condemned, a number of these having suddenly broken in two like glass. 6 per cent. reached the thirty-second limit. 25 per cent. varied one-sixty-fourth of an inch from the standard size, while the balance of 65 per cent. were bored to size.

A full description of the boring plant having been given in the *American Machinist* of July 20, 1893, I simply call attention to the more important points which seem of interest and many of which have not been given in said article.

Fig. XX shows the arrangement and details of one of the boring machines. The pipe to be bored, *A*, rests in a fixed support *B* and an adjustable support *C*. The long bar *D*, which is made as light as is consistent with the torsional strain to be transmitted, is carried by two ordinary pillow blocks, *EE*, and driven by the gear *F*. On the end of this bar is carried the cutter head *G*. This is pulled through by the feed-screw *H*, which passes through a bearing *K*, clamped to the end of the pipe itself. The screw is splined its full length, and a feather in the bearing *K* prevents its turning. The hand wheel *L*, which carries a split nut, serves to advance the feed-screw. Opening the split nut permits the

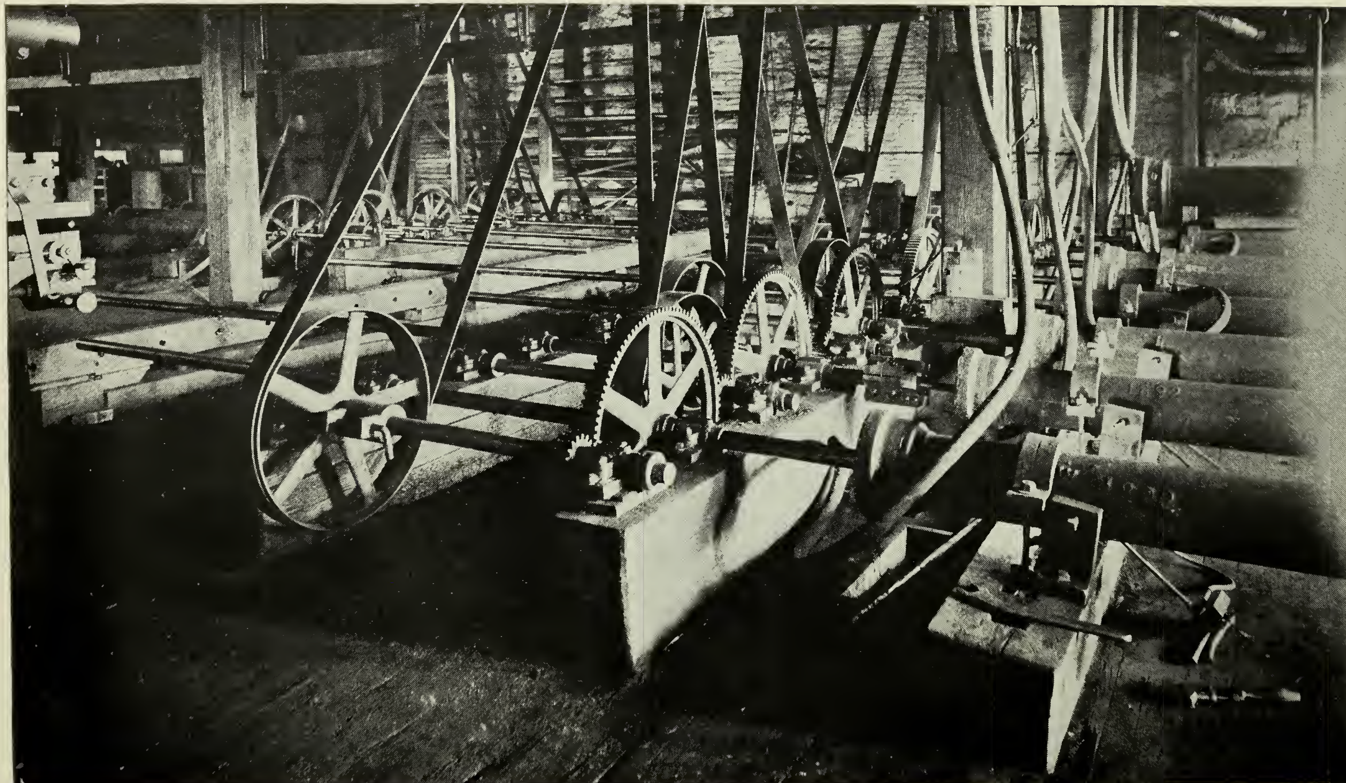


Fig. XXI.—View of Pipe Boring Shop, Philadelphia.

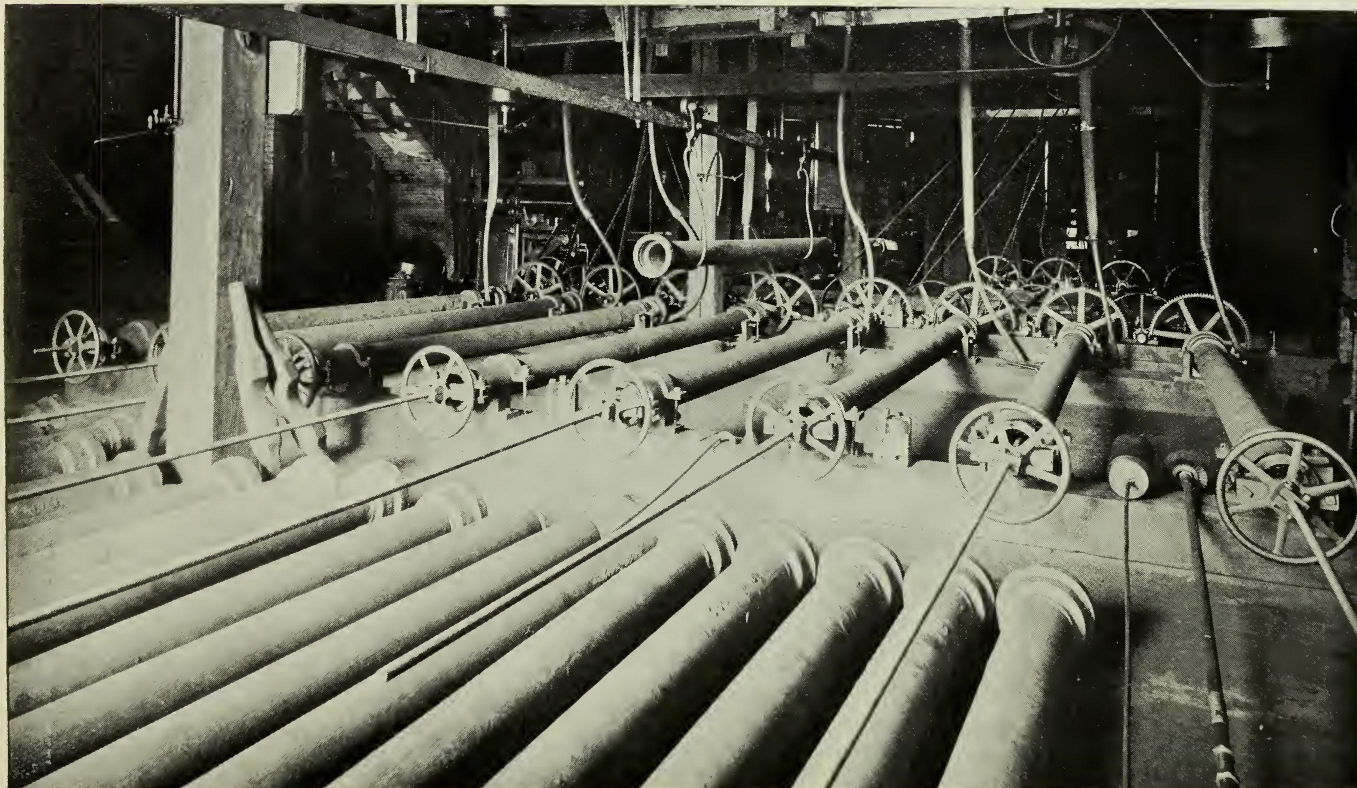


Fig. XXII.—View of Pipe Boring Shop, Philadelphia.

bar to be quickly withdrawn. Hose *M* serves to supply air for blowing out chips and cooling the cutters. Figs. XXI and XXII show views of the plant, which, with the above explanation, will be readily understood.

As the pipes were laid in December and January, during one of the severest winters recently experienced in this part of the country, great difficulties were encountered from snow and frost. The ground was frozen forty inches deep in some places, and could only be opened by building huge bonfires to thaw it out.

In conclusion I would call attention to the fact that mechanically pneumatic propulsion is not economical, about 90 per cent. of the power being wasted in accelerating the air and overcoming its friction, the useful work of moving the carrier requiring but 10 per cent. of the total amount that has to be performed. Commercially, however, the results are very different. In the telegraph service in London not only has the economy in time been demonstrated, but as far back as 1871, Mr. Varley stated that the money saved on clerks' salaries and messengers more than paid the cost of working the plant and interest on the investment.

The tubes to be laid in Philadelphia will be much larger than those used in London, and will therefore permit a far more remunerative class of business to be done. It is now proposed to gradually extend the system all over the city for the purpose of transmitting parcels from the large business houses, as well as for the transmission of the United States mail.

The system of tubes will be laid according to a plan which will be a combination of the radial and circuit systems. The main central pumping station will be established in the vicinity of Twelfth and Market Streets. There will be other central pumping stations located at several points in the city, which will be connected by a radial system of tubes with the main central station.

Each central station will be the nucleus of a number of local circuits covering territory within convenient limits. On these circuits sub-stations will be established about six blocks apart, so that packages and messages can be quickly delivered to intermediate points by boys.

In the further development of the system no doubt many problems will arise, and there is promise of much that will be of interest to the engineering profession in this new field of activity.

Note.—The author has made use of some illustrations taken from Post Office Telegraphs 1891, published by the British Post Office, also from the London journals, *Engineer* and *Engineering.*

The following is a record of the literature on the subject of Pneumatic Tubes, as far as the author was able to obtain it:

Proceedings of the Institute of Civil Engineers, Vol. XXXIII, November 14, 1871.
Pneumatic Dispatch Tubes, by Carl Siemens.

Proc. Inst. of C. E., Vol. XLIII, November 16, 23 and 30, 1875.
The Pneumatic Transmission of Telegrams, by R. S. Cully and R. Sabine.
Experiments on the movement of Air in Pneumatic Tubes, by C. Bontemps.
Investigation of motion of light carriers in Pneumatic Tubes, when the air is in continuous motion, by Prof. U. C. Unwin.
Discussions of the above papers.

Nature, November 27 and December 11, 1873.
Description of Paris System.

Engineering, London, October, 1874, to July, 1875.
Pneumatic Transmission.

The Engineer, London, December 18, 1891.
Our Postal Telegraphs.

Telegraphs, British Post Office, 1891. (Official Publication).
Technical Instructions No. X. Pneumatic Tubes.

Archiv für Post und Telegraphie, Berlin, 1888. (Official Publication.)
Rohrpost-Anlage zu Berlin und Charlottenburg.

Zeitschrift des Vereins Deutscher Ingenieure, February 7, 1891.
Rohrpost-Anlage, Stettin.

Annales Télégraphiques, Paris. (Official Publication.)
La Télégraphe Pneumatique, par Ch. Bontemps, 3d series, Vols. I and II.
Expériences sur le mouvement de l'air dans les tubes pneumatique, par Ch. Bontemps, 3d series, Vol. III.
Récherche des dérangements sur les tubes pneumatiqes, par Chas. Bontemps, 3d series, Vol. VII.
Application des tuyaux au transport des dépêches en Angleterre, par Grosjean, 2d series, Vol. IV.
Télégraphe Pneumatique à Berlin, 2d series, Vol. VII.
Télégraphe Pneumatique à Paris, 3d series, Vols. I and XI.
Les Machines du service pneumatique au nouvel Hotel des Postes à Paris, par Wunschendorff, 3d series, Vol. XII.

Les Télégraphes, par A. L. Ternant, 1881. Hachette & Co., Paris.

Rapport de l'inspecteur des Télégraphes Belges, par M. Delarge. Bruxelles, 1879. (Official Publication.)
Van Nostrand's Magazine, Vol. III, 1870.
Pneumatic Transmission through Tunnels and Pipes, by Robert Sabine.
Van Nostrand's Magazine, Vol. XIV, 1876.
Experiments on the Movement of Air in Pneumatic Tubs, by Ch. Bontemps.
Engineering Magazine, February, 1893.
Progress in Pneumatic Transmission, by Wm. Allen Smith, E. M.

DISCUSSION.

After opening the discussion upon Mr. Falkenau's paper, the President introduced Mr. W. W. Carr, Postmaster of Philadelphia, who stated that the tube had been placed in the hands of the Government before his appointment, and that much of the credit for its installation was due to the indefatigable energy and persistency of his predecessor, Mr. John Field.

The subject is one of great interest, not only to engineers, but also to the general public on account of the direct return received through the increased efficiency of the mail service.

The tube has carried 30,000 letters per day, and has been working most satisfactorily and without a single stoppage. Great credit is due Philadelphia for introducing the first pneumatic system in the United States. Chicago and other cities are contemplating following our example.

Mr. John Field explained that he felt the need for improvement in the methods of handling the Philadelphia mails as soon as he entered upon his duties as postmaster. He visited European cities to learn the best methods in vogue, and decided to recommend the adoption of a system similar to that in use in Berlin. More or less meritorious designs were offered by different companies, but the greatest difficulty was to obtain the permission of the Government to make the trial. The system finally adopted has proved entirely successful and reflects great credit upon its constructors, as well as its designers.

Mr. W. J. Kelly, President of the Pneumatic Transit Company, was asked to address the Club, and responded with a few remarks explaining the policy of the company and describing some of the unavoidable difficulties that he had to contend with.

Mr. B. C. Batcheller was introduced by the President, and

spoke of the advantages of the present system, citing a case of special delivery where more than three hours had been saved in transit from Philadelphia to New York. Referring to details, he said that the most economical speed of carrier was about 30 miles per hour, and the actual time the mail was in the tube was but a very small part of the total time in handling. An increase in velocity would add to the wear and tear, with but little gain. This same speed is used in the Continental lines.

The diameter of the tube was determined only after mature deliberation. The original intention was to use 6-inch wrought-iron pipe; but finding the diameters varied too much, 6-inch cast-iron water-pipe was used, bored out to $6\frac{1}{8}$ inches. This capacity has proved ample, and is by far the largest in the world. Each carrier holds about 200 letters, but 100 to 150 should be taken as the average, which, at the rate of 8 carriers per minute, gives a delivery of 48,000 letters per hour. The time required to make the distance between the two post-offices is about 57 seconds, and the carriers will run about 550 miles before the packing-rings placed on the outside to form air-tight joints will wear out. This packing was formerly made of felt, but it is now found that canvas answers the purpose very well.

The best form of carriers are those with open ends, as this gives a much stronger shape than those with the openings on the side, and there is much less danger of breakage. The largest size of pneumatic tube considered feasible was about 8 or 10 inches in diameter, as beyond this size the carriers increase so rapidly in weight that the packings, upon which the whole weight rests, would soon wear out. The length of such a line should not exceed 4 miles.

Mr. Batcheller closed with some interesting conclusions drawn from his experience regarding the advantages and applicability of the polygonal system, giving special reference to the enlargement of the Philadelphia plant.

XII.

ELECTRO-METALLURGY OF GOLD AND SILVER.

By A. L. Eltonhead, Active Member of the Club.

Read, May 5, 1894.

[At the author's request the publication of this paper is laid over for the present.—Pub. Com.]

XIII.

NOTES ON THE IMPROVEMENT OF PHILADELPHIA HARBOR.

By L. Y. Schermerhorn, Active Member of the Club.

Read, May 19, 1894.

The improvement of Philadelphia harbor is so intimately associated with the Delaware River as a whole, that a brief consideration of the river's tides and their movements is pertinent to the subject of the improvement of the harbor at Philadelphia.

The two flood and ebb tides which move through the river each day are simply the impulses of waves generated in mid-ocean and impinged upon the river at its mouth. The crests of these waves form the high water and the troughs the low water; while that part of the wave in front of the crest the flood tide or rising water, and that part of the wave behind the crest ebb or falling water; consequently the flood tide or rising water and ebb tide or falling water both move up the river. As illustrative of this statement, a vessel entering the Capes at full high water or dead low water could keep either of these stages of tide all the way to Philadelphia by a proper rate of vessel speed. The direction of the movement of these crests and troughs must not be confused with the direction of flood and ebb tide currents.

Sir William Thomson has reached the conclusion that the full ocean wave does not exceed about one and one-half feet in height, but we find this height varying from about 4 feet along the middle and south Atlantic coast to 50 feet or more at the Bay of Fundy. These deformations of the ocean wave are due to the configuration of the ocean bottom and shores upon which the wave falls.

Theoretically, one crest of the tidal wave should be nearly under the line joining the earth and moon at their nearest points, and the other crest 180° of the earth's circumference therefrom, but practically the crests of the waves lag more or less behind such points; at the mouth of the river the tidal crest is 8 hours 16 minutes behind the moon's transit across the meridian; at Philadelphia 13 hours 48 minutes, and at Trenton 16 hours 50 minutes behind the moon's transit.

Since there are two tidal crests and two tidal troughs each lunar day, we find the crest and trough separated at the mouth of the river by an interval of about 6 hours and 12 minutes. After the wave has entered the river its crest and trough cease to travel at the same rate of speed, for reasons which will be alluded to later; and the crest or high water reaches Philadelphia in about 5 hours and 32 minutes after entering the mouth, while the trough or low water lags more and more behind, requiring 6 hours and 52 minutes for its passage. The velocity of the crest is about 18 miles, and the trough about $15\frac{1}{2}$ miles per hour in passing from the mouth of the river to Philadelphia.

Theoretical considerations indicate that the velocity of a wave impulse is equal to the velocity a body would acquire in falling through a height equal to half the depth of water in which the wave moves. Since the average rise of the river's surface, for its whole length, at flood tide or high water is between 5 and 6 feet, it follows that the crest of the wave is running in water from 5 to 6 feet deeper than the trough, consequently its velocity should be greater, as it is found to be in fact.

If in the formula $v = \sqrt{2\, g\, \frac{d}{2}}$, the above-named values of v are substituted, it will be found to give values for d, or depth of 22 feet for high water, and 17 feet for low depth as the mean

depths of the entire river; these values practically agree with the facts, and their difference is about equal to the difference between high and low water.

In the passage up the river of the tidal crest and trough we find them separated by an interval of time which is such as to make it high water at Philadelphia at the same time that it is low water at the Capes, and *vice versa;* you must, therefore, think of the water surface of the river as nearly a plane surface, slightly deformed at either end, alternately tilted up and down four times each day.

Of the exact position of this tilting plane in reference to sea level as datum, the only statement that I know of worthy of credence is found in the Report of the Geological Survey of New Jersey for 1886, which shows that:

Half tide at	Philadelphia	is	0.34	ft.	below	mid-sea level.
Low water at	"	"	1.09	"	"	L. W. at Capes.
High " "	"	"	0.42	"	above	H. W. at "
" " "	"	"	4.9	"	"	L. W. at "
Low " "	"	"	5.6	"	below	H. W. at "

These elevations give slopes of the water surface varying from $\frac{6}{10}$ to $\frac{7}{10}$ of an inch per mile of river.

The progress of the tidal crest or high water, and the trough or low water, must not be confused with actual tidal current velocities, since the former are waves of oscillation and with probably but little motion of translation, while the current velocities are purely those of translation and induced by the slope of the water surface along the front and back of the wave crest. The velocities of the crest and trough of these waves are about 25 feet per second, while the current velocities are only from 1 to 3 feet per second. Upon the two slopes of the wave crest the tidal currents are flowing in opposite directions or away from each other, while upon the two slopes of the trough the tidal currents are flowing in opposite directions but towards each other.

Experience has shown, in the improvement of tidal rivers, that by a proper increase in channel depths and the removal of obstructing bars the passage of the tidal wave is facilitated by the increase in the mean depth and the time for the passage of

both high and low water up the river materially reduced. With such improvements there has also been an increase in the amplitude of the tide in the upper or improved reaches of the river. In fact, such indications of tidal phenomena are accepted as measures of the efficiency of the improvement.

At Philadelphia the duration of the flood tide is 5 hours 12 minutes, and the ebb tide 7 hours 12 minutes; at Burlington, 4 hours 56 minutes and 7 hours 28 minutes; and at Trenton the head of tidal influence, 4 hours 22 minutes and 8 hours 3 minutes.

The paths of the flood and ebb tide currents are of essential importance in the improvement of a tidal river, and upon their control the success of the engineer mainly depends. In long, straight reaches of the river the paths of flood and ebb generally coincide, while in curved reaches or at areas widened by islands or shoals their paths are very liable to be divergent. In general terms the ebb currents follow such paths as would be found to exist in non-tidal rivers; while the flood tides, having once obtained their directions from straight reaches of the river, tend to persevere on such paths until stopped by banks or shoals. Very generally flood-tide channels near curved parts of the river are found running into useless and blind channels, and ending in a *cul de sac.*

The area of the tidal basin inside of the Capes is about 800 square miles, while the area of the basin about Philadelphia is about 15 square miles; these areas are in the proportion of about 53:1. The high water cross-section at the Capes is about 300,000 square feet, and at Philadelphia about 70,000 square feet, or in the proportion of about 43:1.

This tidal basin of 15 square miles above Philadelphia is the measure of the tidal volumes which move through the harbor of Philadelphia and the forces which must be considered in the plans for its improvement. Gaugings which were made a few years ago indicate that about 2,000,000,000 cubic feet of water pass through the harbor of Philadelphia with each ebb tide, and about 1,860,000,000 cubic feet with each flood tide; this volume, about 245,000,000 tons of water, passing twice each twenty-four hours through the harbor.

The difference between the ebb and flood tide's volume arises from the inflow from above tidal influence at Trenton, and this volume adds about 7 per cent. to the flood tide volume. Gaugings of the river above tidal influence indicate a flow for the mouths free from freshets of about 3,300 cubic feet per second; this would be equal to a stream 400 feet wide, 4 feet deep and flowing with a velocity of about 2 feet per second. This comparison will permit you to appreciate how much of the present dignity of the river is due to the imported tidal wave.

Returning to the 2,000,000,000 cubic feet of water flowing through the harbor with each tide, we are confronted with the real problem that the engineer has to grapple with in the improvement of the harbor. Dependence must be mainly placed upon the tidal currents for the maintenance of new channels, and these currents are in turn dependent upon the filling of the tidal basin above the harbor. Since the harbor of Philadelphia is the gateway to this basin, we receive a suggestion which forbids any dangerous interference with the entrance and exit of the tidal volume to or from the basin above the city.

The engineer finds in the unimproved condition of the harbor a mean low water cross-section of about 55,000 square feet in a bifurcated channel at two localities, viz: at Smith and Windmill Islands and at Petty Island, and the plan for improvement becomes, with other requirements, the unification of these channels.

Time forbids more than a passing allusion to the entirely unimproved condition of the river at Philadelphia; suffice it to say that in early times Front Street upon the Philadelphia side and Second Street on the Camden side formed the old river banks, giving the river below Petty Island a natural width of from 4,000 to 4,600 feet; in 1819 these widths had been reduced to about 3,300 feet, while at the present time they are about 2,400 feet. The project for the improvement of the harbor now in progress of execution reduces these widths to 1,900 feet.

In its natural condition a bar just showing at low water extended from about the foot of Christian Street to Cooper's Point; part of this bar became subsequently Smith and Windmill Islands, by being built about with artificial revetment and filled

with ballast, etc., until they became the islands of recent memory. Petty Island was high enough to keep its surface out of the water until the tide had risen to about half its height, and after which it became submerged. Subsequently earthen dikes reclaimed about 150 acres from overflow, and still later wharves were built and land filled in along the north front of the island.

The general indications from a comparison of successive surveys are, that the general cross-section of the river has been quite constant during the encroachments upon its width, and that these reductions in widths have been compensated for by increase in depths. This principle seems generally true for the entire river, in which through the reduction of high water widths by dikes to reclaim land along its borders, there has been a general increase in the mean depths of the river.

About twelve years ago the question was first suggested of removing in whole or in part the obstructing islands and shoals, but it was not until 1888 that the subject assumed definite form through the report and project of a Board of Engineers, called into existence by the action of Congress, which in turn had been prompted by the action of commercial interests and City Councils, who became pledged to the National Government to undertake at the proper time the necessary pier and avenue extension, if the work outside of the harbor lines should be undertaken by the Government.

The problem simply stated was the readjustment of the river in front of Philadelphia so as to permit the extension of wharves to a length of from 500 to 600 feet, and the widening of Delaware Avenue from a width of 50 feet to that of 150 feet. The effect of this combined extension of avenue and wharves would result in an extension of the piers from 400 to 500 feet beyond their present lengths. Opposed to such an extension stood Smith and Windmill Islands and their adjacent shoals, and Petty Island and its shoals. To remove the interfering islands and shoals without an advance of the wharf lines, would have been to greatly increase the cross-section of the river beyond its normal area of 55,000 square feet.

The first point to establish was the extent of widening on Delaware Avenue necessary to give proper facilities to the pro-

posed wharves, and next the length of wharves required to meet the demands of modern ships. These established, the proposed lines limiting the extension of construction upon the two sides of the river could be placed upon the map and gave a remaining width of 1,900 feet to the waterway. To preserve the normal section of 55,000 square feet, suitable dimensions for the needs of commerce and this section were fixed upon, giving a least depth of 26 feet at mean low water for a width of 1,000 feet from the Philadelphia harbor line, and for the remaining width of 900 feet a depth decreasing from 26 feet to that of 12 feet at low water along the Camden front. These conditions and conclusions fixed the limiting lines along the Pennsylvania and New Jersey front, and upon the recommendations of the Board of Engineers the Secretary of War fixed these lines as limits beyond which no piers could be extended.

At the upper end of Petty Island the channel in its natural condition divides into two branches flowing along the north and south sides of the island. Even before the project for the improvement of Philadelphia Harbor had been adopted the necessity for the closure of the channel south of Petty Island had become a part of the general scheme for improvement of the river at and just above the island, and Fisher's Point dike had been partly built. Ultimately this dike will be connected with the upper end of Petty Island and the entire tidal volume diverted into the Pennsylvania channel.

Along Petty Island the channel is widened by cutting away a triangular area from the north side of the island, starting at a point at its upper end and increasing to a width of about 900 feet at its lower end. The length of this triangular area is about $1\frac{1}{2}$ miles; by this the Philadelphia channel at the lower end of the island is increased from its previous width of about 1,000 feet to its new width of 1,900 feet.

This in general terms is the outline of the project for the improvement of the Delaware River at Philadelphia, involving the entire readjustment of about six miles of river extending from Fisher's Point to Kaighn's Point, and requiring the excavation of 25,000,000 cubic yards of material, at an estimated cost to the United States of $3,500,000 and a much larger amount by the

city and its allied commercial interests through the widening of Delaware Avenue and the extension of wharves.

Work under this project was commenced three years ago, but after two years' operation, in which the contractor removed about 800,000 cubic yards of material, the contract was annulled, and last June the work renewed under a new contract. Since that date about 4,600,000 cubic yards of material have been removed, at a monthly average rate of over 400,000 cubic yards; the highest monthly output was reached in January of this year in the excavation of 540,000 cubic yards.

The first working year under the present contract will end on June 30, 1894, at which date 5,000,000 cubic yards will have been excavated. This quantity will be 2,000,000 cubic yards beyond the requirement of the contract. During a part of the year 14 dredges, with 90 scows, were engaged upon the work of excavation, and 2 hydraulic dredges in placing material ashore at League Island, making by far the largest dredging plant which has ever been assembled upon any work in the United States.

The material constituting the river bed and under those parts of the islands which are artificial, consists of varying proportions of clay and sand, except in the vicinity of Port Richmond, where glacial drift is encountered, consisting of gravel and bowlders mixed with stiff clay. Below Petty Island rock is not found at less depth than from 75 to 100 feet, but on the Philadelphia shore, opposite Petty Island, rock is found at the inner ends of the pier at depths of 10 to 20 feet below the surface of the water. This rock foreslopes abruptly to the south and quickly passes under any depth required for navigation.

In the work already done there was no tendency to shoaling over the dredged areas, and any that may be apprehended will probably be a local shifting of material. The Delaware River, from the small amount of water which comes from above tidal influence, is not a silt-bearing stream, and for this reason the engineers have strong grounds for expecting permanency of depths in properly located artificial channels, especially when such readjusted channels preserve the normal cross-section of the river.

Under the general jurisdiction which Congress exercises for the

conservation of the navigable waters of the United States, the Secretary of War is authorized to establish harbor lines beyond which no wharf or pier can be extended, and to fix regulations controlling the general construction of such wharves and piers. Under this authority and upon the advice and recommendation of a Board of United States Engineers, bulkhead and pierhead lines have been established along both sides of the river at Philadelphia, and the following regulations controlling the construction between these bulkhead and pierhead lines issued:

"Under the provisions of Section 12 of the Act of September 19, 1890.

"1. All piers hereafter constructed or extended must extend to the pierhead line.

"2. No cribs or other solid structure shall be hereafter constructed between the bulkhead and pierhead lines below a level 2 feet above mean high water.

"3. In the construction of new piers or the extension of old ones, the pile groups supporting the superstructure shall be at least 10 feet apart."

This control on the part of the United States is the exercise of a wise authority conferred by the recent acts of Congress, all tending to the conservation of the navigable waters of the United States, and which is beyond the recklessness of politics or the selfish and unthinking caprice of the individual.

A few words in explanation of the plans for bulkhead and pier construction as outlined by Major C. W. Raymond to the Board of Harbor Commissioners, may be of interest. The bulkhead or harbor face of the solid filling would be required to act as a retaining wall about 36 feet in height, and was to consist of a pile substructure filled with stone surmounted by a concrete superstructure faced with stone masonry. This structure would be continuous and bounding the east side of Delaware Avenue for its entire length.

The pier construction must consist of piles surmounted with a timber deck after the general construction of the recent New York piers. The piles in the substructure to be placed in bents about 10 feet from center to center of bents, and carried to a height of 8½ feet above mean low water, above which would be

placed the deck of the pier. The superstructure was to provide for carrying a safe load of 1,000 pounds per square foot of deck. The cost of such a structure has been estimated at about $1.25 per square foot of deck. Special requirements might demand a more or less substantial construction than that outlined in the above; all of which would be attainable by the necessary modifications in details.

This, in general terms, is the project and its development for the improvement of the port of Philadelphia and by which an opportunity will be given for the construction of six miles of wharves along the city's frontage, with a length suited to the demands of modern commerce and with a channel depth of 26 feet at low and 32 feet at high water.

In the time to come, when the commerce of the port shall rise to the utilization of such wharf facilities, the wisdom of those who prompted and designed such a system will be a proud memory and the city truly then be entitled to the name of New Philadelphia.

DISCUSSION.

Mr. John Birkinbine: With the present width of channel, after heavy rains Delaware Avenue is often flooded, and I would like to know what effect the narrower channel would be likely to have, especially at times when freshets may occur in the river.

Mr. Schermerhorn: The flooding that you refer to on Delaware Avenue is due to backing up of the water under storm tides and a heavy wind, and freshets in the upper river have very little effect on the water surface at Philadelphia.

Mr. C. L. Prince: The depth of the channel in front of Camden, which Mr. Schermerhorn has given is 12 feet, but as the piers are to be of piles, the depth at their outer ends would of course be greater, and large enough for all of the traffic that now comes to that city.

Mr. Robert A. Cummings: I would like to know regarding the mean velocity of the tidal flow at Philadelphia, how much it was before the improvements were begun, and what it is esti-

mated to be after completing the narrowed channel, and also whether the bottom velocity will scour the bed of the river.

Mr. Schermerhorn: The present mean velocity of the river is about 2 feet per second, and we expect that after the improvements are completed, it will be nearly the same. Regarding the scouring of the bottom, it is not expected that any increased velocity will have any material effect upon it.

Mr. Cummings: I have observed that the material on Petty Island is laminated in horizontal layers alternately of clay and sand from $\frac{1}{8}$ to $\frac{1}{4}$ inch in thickness, and extending down to a depth of over 20 feet, and this recalls to my mind a similar state of affairs on a tidal river of the Wash, in England, where the tidal deposits of mixed clay and sand are so rapidly formed that the land has been continually reclaimed from the sea since the time of the Roman occupation. Will Mr. Shermerhorn explain to us how these laminations occur on Petty Island?

Mr. Schermerhorn: This is a very interesting occurrence, but I have no satisfactory reason to give for it. It does not seem to be confined to the one locality, however, but this formation exists in different places all along the Delaware River, and at all depths.

Mr. John C. Trautwine, Jr.: In a recent trip on the river with a party of electrical engineers, we were discussing the capacity of the scoops in the dredges, and I would like to know what is the quantity of material which they carry.

Mr. Schermerhorn: Most of our scoops hold about four cubic yards, and at the present rate of working we can excavate about 400,000 cubic yards per month. I was asked regarding the strain on the two chains that carry the scoop in the dredge, and while I have no exact information at hand regarding it, should judge that it is from 40,000 to 60,000 pounds, depending upon the size of the dredge.

Mr. Birkinbine: Before this discussion closes I would like to emphasize a fact to which I have called your attention before, namely, that we have in our own membership men who are engaged in work of great importance and engineering interest, and if they will take the trouble to explain this work to the Club, as Mr. Schermerhorn has done this evening, I am sure that we need have no lack of interesting and valuable papers.

[On June 16th, Mr. Benjamin Franklin read the following discussion on Mr. Schermerhorn's paper, prefacing his remarks by explaining that the discussion had been prepared jointly by Prof. L. M. Haupt and himself.—Pub. Com.]

Prof. L. M. Haupt (*visitor*) and Mr. Benjamin Franklin: It has never happened that so large a contract has been undertaken by the Government for the improvement of the channel in front of our harbor as at this time, involving the removal, according to the latest statement, of 22,000,000 cubic yards. The estimate at the last letting of the contract was 21,500,000, and the estimated cost $3,500,000, while the city is expected to expend about $8,000,000 in advancing her piers to the new lines established by the Secretary of War. It is of great importance, therefore, that the problem should be carefully stated, be thoroughly understood, and be judiciously executed. The issues are vital to the welfare of the city as a commercial center.

In the paper under consideration with reference to the upper river, the record states as follows:

"We dare not interfere with the entrance and exit of the tidal volume to this basin above the city, since the harbor of Philadelphia is essentially the gateway of the basin."

While this is true, and its importance was fully stated by the Advisory Board to the Harbor Commission as early as 1883, when the question of the dike at Petty Island was under consideration, yet the dike was built where it would interfere most with the ingress of the tide to the upper river reaches. Again, it has been urged recently that in the advance of the wharves to the new lines, their construction should begin at the lower end of the rectified channel near Moore Street. This would have the effect of separating still more than at present the paths, or loci, of mid-volumes of flood and ebb currents, which is just what should be avoided, as far as possible. This method of procedure must result in increasing the deposits over the site of the island until the plan is completed and the up-river piers are advanced on the Pennsylvania side.

It is also stated in the record, that—

"The minimum width of channel . . . should be about 1,900 feet, with such depths as would give, with the islands removed, a cross-section of about 55,000 square feet."

"This was obtained by giving the channel a least depth of 26 feet at mean low water for a width of 1,000 feet from the Philadelphia front, and for the remaining 900 feet the depth gradually decreasing to about 12 feet along the Camden front. Upon the recommendations of the Board of the United States Engineers, the Secretary of War then fixed the limiting lines beyond which no piers could be extended."

These dimensions appear to differ sensibly from those given in the Annual Report of the Chief of Engineers for 1893, where it is stated that the project of the Board of Engineers of 1888 provided "for the removal of Windmill and Smith Islands and the adjacent shoals, so as to form a 26-foot channel about 1,000 feet wide or wider if found practicable," and to widen the Pennsylvania channel at Petty Island so as to give a mean width of about 2,000 feet, a depth of 26 feet over a width of about 1,000 feet, more or less, the channel sloping to a depth of 12 feet in the remaining width, and a resulting cross-section at *half-tide* of about 55,000 square feet.

The project further provides for the *simultaneous* regulation of the Port Wardens' line of both shores of the river, so as to maintain the assigned section of the new channel and the establishment of these lines by actual construction during the progress of the work. The reconstruction of the water fronts to conform to the new lines will be executed at the expense of the cities of Philadelphia and Camden, or the riparian owners. The cost of this reconstruction for a portion of the Philadelphia front from opposite Kaighn's Point to opposite the lower end of Petty Island, exclusive of the cost of property for widening Delaware Avenue, has been estimated at about $8,000,000.

The inconsistency of these two statements is more manifest when it is observed that the smaller section measured from mean low water is estimated to give the same sectional area (55,000) as the larger one measured from " half-tide."

With reference to the velocities to be expected after the readjustment of the section the record states:

"The present mean velocity of the river is about two feet per second, and we expect that after the improvements are completed, it will be nearly the same. Regarding the scouring of the bot-

tom, it is not expected that any increased velocity will have any material effect upon it." These conclusions do not seem to be justified.

Because of the fact that the new piers under the plans now on file in the Department of Public Works, will not be permitted to be filled in solidly to the outer or pierhead line, so that there will be no adequate compensation for the removal of the space volumes occupied by the islands.

The basic principles which govern the above questions are, first, that for a constant discharge the velocity varies inversely as the area; and, second, that the ability of a stream to scour varies directly as the square of its velocity. If, therefore, the area is to remain constant at 55,000 square feet, as proposed by the Board, there will be no material change of velocity, consequently there could be no change in the regimen of the stream as to its capacity to scour or deposit. It is, however, a fact, that if the present area before the removal of the islands is 55,000 square feet, as stated both by the U. S. Engineers and the U. S. Coast Survey, then, as the cross-section of the islands below mean water is about 25,000 square feet, their removal must increase the area to this extent, and the total area, unless compensated for, would be 80,000 square feet. To extend solid piers on the Camden side 650 feet would consume about 5,000 feet of this area; and on the Pennsylvania side, if solid, a 650 feet extension from the present bulkhead line would consume about 20,000 square feet, thus almost exactly compensating for the removal of the islands and maintaining the normal section, as was contemplated by the Board of Engineers.

But if, on the contrary, this sound fundamental principle be violated, it must result in permanent injury to the navigable stream, and hence it is that we look with grave forebodings upon the proposition to support the pier upon open piles, spaced 10 feet apart from center to center, for the express purpose of permitting the current to flow freely through and under the piers back to the bulkhead line. If we assume that 20 per cent. of this area may be occupied by the piles, then the enlargement of the waterway would be about 16,800 square feet or over 30 per cent. of the normal section of the stream, resulting in consequent

reduction of velocity and deposits in proportion to the square of that reduction.

It seems, therefore, that there is no escape from the conclusion that the attempt to introduce the open pier method of construction, as used in New York Harbor, into this port can only result in permanent injury to the navigable channel and should not be permitted, and, as the Secretary of War has jurisdiction only over the "harbor lines" it is a matter for our local organizations to carefully consider before committing the city to so serious a mistake.

Again the record remarks:

"As only 7 per cent. of the water in the Delaware River comes from above tidal influence, it is not a silt-bearing stream, and consequently the engineer has strong grounds for expecting permanency of depths in properly located artificial channels, especially when such channels preserve the normal cross-section of the river."

The conclusion in the above paragraph appears erroneous, because, in the first place, the section as proposed to be built is not the normal one of 55,000 square feet; secondly, because the dredged channels which have so often reopened do not maintain themselves as a matter of fact; and, thirdly, because the visible appearance of the water itself gives every indication of its being charged with silt.

It is not the small ratio of fluvial to tidal water that determines whether a river is silt-bearing so much as the character of its bed or the geological formation through which it flows; and as the Delaware's bed is alluvial and readily abraded by the ordinary currents, it is evident that permanency of result can best be obtained by regulating works, and no dependence can be placed upon dredging without such auxiliary structures.

With such works it would be entirely possible at comparatively small cost to secure and maintain an ample channel to the sea for our deepest draft vessels and, as there are about twenty miles of shoals, according to the Engineer's reports, between Philadelphia and Bombay Hook, the importance of such works cannot be too strongly urged.

The fact of the "laminations in horizontal layers alternately

of clay and sand from $\frac{1}{8}$ to $\frac{1}{4}$ inch in thickness, and extending down to a depth of over 20 feet," is sufficient evidence of the sedimentary character of the stream as noted on Petty Island by Mr. Cummings; whereas Mr. Schermerhorn does not so regard it, for he is said to have remarked in reply:

"This is a very interesting occurrence, but I have no satisfactory reason to give for it. It does not seem to be confined to the one locality, however, but this formation exists in different places all along the Delaware River."

This statement would seem to confirm the opinion of others that it is a silt-bearing stream. In fact, the flood tide enters the river carrying the sediment up-stream along the shore so that in many places the mouths of the tributary creeks work up-stream as do the shoals and islands, and the changes which are thus recurring are fully shown in the scouring away of the island which existed opposite Red Bank during the Revolution, and the filling of back channels which were then navigable for the British frigates, all through natural agencies. The mouths of the Schuylkill and Christiana are working up-stream, as has been shown hitherto by Prof. Haupt in his studies and reports on Tidal Rivers.

It would seem, therefore, that the present state of the harbor problem is a very unsatisfactory one, and that no departure should be permitted to be made from the well-digested general plan recommended by the Board of Engineers in 1888, but that the regimen of the river should be preserved by a lateral movement of the material from the islands to either shore. By this means the form of the cross-section may be changed without materially affecting the areas of the sections, while the path described by the material removed, or in engineering parlance the "average haul," will be reduced to a minimum. This will give, therefore, the most economical result, as well as the greatest profit to the contractor at existing prices.

Prof. Haupt stated that in view of the great expense involved it was important that the plan be thoroughly digested, and showed by diagrams and figures that the total normal cross-section as designed by the Board of U. S. Engineers of 1888, would be located between the pierhead lines, and that the modified proposition to

build open piers would, in consequence, largely increase the sectional area and reduce the velocity of the currents, whereby their ability to scour would be diminished at least 40 per cent. The compensation for this enlarged section would take place in the navigable stream, to the eastward of the center, and would amount to a shoal of not less than 10 feet in height by 800 feet in width of sections, thus reducing the required navigable depth at mean low water from 26 to about 16 feet, and rendering constant dredging necessary.

As it was suggested that the vessels in the docks would act as a substitute for solid piers, Prof. Haupt objected that the currents would scour out deep pockets under them and this material would be dropped in adjacent docks or in the stream itself, making the bottom lumpy and requiring additional dredging. It was thought to be unwise to expect the vessels to do the work of a permanent structure.

Mr. L. Y. Schermerhorn: Appreciating that the work under consideration is of great importance and therefore "should be carefully studied and thoroughly understood," I shall very briefly allude to the main points raised in the foregoing discussion.

Petty Island dike, when completed, will simply form an artificial shore in prolongation of the natural one, to a part of the rectified and improved rim, and as such will oppose no more interference to the ingress of the flood tide to the upper river reaches than will any other part of the New Jersey or Pennsylvania shore.

The advance of the wharves was to begin at Moore Street, the lower end of the rectified section, simply because it was the first point of the river which could be made ready for such advance. The apprehension of evil to arise from doing something which may not be exactly approved of by "the paths or loci of mid-volumes of flood and ebb tide currents," is a sounding but empty fear.

The inconsistencies of statements adduced by Mr. Haupt, as to the new sections of the river, are simply inconsistencies between the real facts, and Mr. Haupt's apprehension of the facts, and for their harmony I am not responsible.

As to the jurisdiction of the Secretary of War, through the

acts of Congress, over the character of the constructions between the bulkhead and pierhead lines, all that can be said is that Mr. Haupt holds an opinion which is in conflict with that of the executive departments of the Government.

Experience abundantly establishes the fact that the Delaware River is not a silt-bearing stream ; the conclusions of Mr. Haupt to the contrary, based upon some dredged channels refilling, and the laminated character of parts of the bed, are misinterpretations of the evidence. In Philadelphia harbor the refilling of dredged channels has always arisen from the local movement of material from the near vicinity of the increased section, and not from the deposition of silt from silt-bearing water: the difference is material and fully recognized by those who have intelligently studied the problem. The lamination of deposits in the old and previously undisturbed parts of the river bed do indicate that they were deposited from silt-bearing waters, just as the deposit of the Trenton gravel near Petty Island indicates that it belongs to the glacial and early post-glacial period ; long after which period the Delaware River was a silt-bearing stream, and during this condition the alluded-to laminated deposit probably occurred ; but with the change in fluvial volumes, due to change in continental modifications, the silt-bearing waters, in which fluvial volumes enormously predominated over tidal volumes, became slowly changed to the later condition in which tidal volumes, with comparatively low elevation, predominate, and with this change an almost complete elimination of silt. Hence these laminated deposits only indicate that in the past, and not in the present, the Delaware River was a silt-bearing stream.

But few problems of river improvement have been as carefully considered as that of Philadelphia harbor, and during the years that the problem has been under review it has been carefully studied in all its phases by the most eminent practical hydrographic engineers, and the plans of improvement now in progress are the well-digested conclusion of such engineers. In the prophecies of evil which Mr. Haupt sees for the future of the improvement, he at least has the distinction of standing alone.

XIV.

REBUILDING THE PENNSYLVANIA RAILROAD AFTER THE JUNE FLOOD OF 1889.

By Joseph T. Richards, Active Member of the Club.

Read, June 2, 1894.

In speaking on the subject of rebuilding the Pennsylvania Railroad after the June flood of 1889, we will first get the date correct, as it did not occur in June, but on the 30th and 31st of May. I have consented to open this subject with much reluctance, and do so with no intention of presenting to this Engineers' Club a pamphlet on surveys or location; nor of bridge building, or what might be called a treatise on railroad construction as we may find in our engineering text-books.

It is my purpose to differ completely from such a treatise, and, therefore, my remarks shall be confined to telling a story of the flood.

A trouble such as this flood, at our age of swift transit in everything, generally begins with a telegram coming over the wires giving word of a heavy rainfall; such messages continue, and lead to much anxiety for the safety of trains and the roadbed.

Then damage is reported.

Officers collect, and remain on duty at telegraph offices during night and day, communicating with employees along the lines. The organization begins to feel it is to be tested for vigilance to prevent the loss of life and ability to repair its torn-up railroad.

We all remember this June flood, as it is called. The destruction was simply appalling. It is enough to say that no writer of that day was able to describe, nor was there found an artist who could portray the destruction which came. The railroads were not alone in their distress, and the officers and employees were called upon with other good citizens to assist the suffering people over the greater part of the State of Pennsylvania and of northern Maryland.

The storm was of a very general character.

It formed in Kansas and Nebraska on May 28th, moved eastward and developed in Pennsylvania on the afternoon of May 30th, when flooding rains commenced in the vicinity of Johnstown, gradually extending over the entire State as far east as Lancaster, and continued almost without cessation for a long period of twenty-four to thirty-six hours.

Measurements taken at different points show that during these periods from 4 to 8 inches of rain fell in localities which were below the general level, and from which it is evident that a greater quantity must have fallen on higher districts and mountain ranges.

This vast amount of rain falling on an area of over 12,000 square miles, caused the most destructive flood known in the history of the country.

Beginning with my personal experience, on the 31st of May, I was during the greater part of the day with three companions, driving across the country for professional observations between Middletown and Hummelstown, near Harrisburg, Pa., where the water-gauge registered a rainfall of $8\frac{2}{10}$ inches. This day's experience would be well worth relating, but it would too much lengthen my story.

Returning to Philadelphia late in the night, I started west from Broad Street Station early on the morning of June 1st with Mr. Frank Thomson, First Vice-President, under his directions to repair our losses. Before arriving at Harrisburg, we found the tracks under water for almost $1\frac{1}{2}$ miles between Steelton and Harrisburg. Without delay, however, we managed to get our train through, the depth of water being over the boxes of the car-wheels.

Finding the water was still rising, we stopped at Harrisburg station to learn the situation and make arrangements for the emergency. These I wish to give you somewhat in detail, and I would not do so except as an example to show what we actually did, from what our minds at that stage of the flood told us was prudent to be done, cut off as we were from almost all parts of the State and judging everything at short range, and in this is the lesson, if I have one, to lay before this learned body of gen-

tlemen as to where the engineering comes into the story, and allow you to draw your own conclusions, and to form your criticisms.

Immediately we started to prepare a complete outfit to work, feed and camp the carpenters, telegraph linemen, laborers, etc., using what we might find about us as available. We changed two baggage cars into kitchen cars, purchasing and placing a cook-stove at each end, making tables and benches for the convenience of the cooks, and laying in a large supply of bread, potatoes, meat, coffee and other provisions. Also purchased a large supply of tin plates, tin cups, knives and forks, coffee-pots and cooking utensils in general for a pretty strong commissary department, at the same time taking the seats out of two passenger cars and making a table of pine boards the full length down the middle of each car, placing one of these cars at each end of a double kitchen car. This formed one of two sets of kitchen and dining cars for the commissary train. A second equipment of the same kind was ordered to follow, which was promptly made and came on after we had left Harrisburg. Day coaches were taken along, with two blankets for each man, for temporary sleeping accommodations.

We also arranged one car loaded with tools and materials for carpenters and trackmen, such as two or three coils of 1-inch and 1½-inch rope, of 1,000 feet each, about fifty kegs of 6-inch and 8-inch cut and boat spikes for bracing and scaffolding use, additions to the carpenters' tools as they were found to be short, and to supply what additional carpenters we would be likely to pick up without tools, several carloads of 3-inch plank, and 12 x 12-inch or 10 x 10-inch lumber which applies so well for trestling, and as much of our standard stringer sizes as could be found was purchased and arranged to follow.

In the search of further light at this dark hour, Mr. Thomson's vigilance succeeded in finding an electric car on the Cumberland Valley Railroad, fully equipped with generators, wires, etc. This car was manned and taken along and proved to be of great service to turn darkness into light at the Montgomery bridge, P. and E. Division, and afterwards at the Viaduct, Pittsburg Division.

During all this preparation at Harrisburg for materials, tools and commissary department, the water was rising rapidly in the Susquehanna River, and I was suddenly informed by the Vice-President, Mr. Thomson, who was managing the line where it could be reached by telegraph, that a passenger train had stuck in the high water between Harrisburg Station and Steelton. By his directions I immediately started eastward to relieve it; first by an engine, but was only able to go a short distance; then securing a boat and after proceeding about $1\frac{1}{2}$ miles down the track, it was reached. The trainmen had proven their value in an emergency by securing a large float of logs and boards, and with this landed the passengers in safety a few hundred feet to the shore, excepting, however, the express messenger, who had valuables in his iron box and was guarding it in the car. I conveyed him with the iron box in our boat to Harrisburg Station. When we left the train the water was level with the floor of the express car.

The water after this rose rapidly, and there was as much as six miles of our track under water, beginning a few hundred feet east of the train-shed at Harrisburg and extending eastward.

On the night of June 1st we remained in the station and found the situation was very serious. At 5 A.M., on June 2d, we started with our trains westward, and after spending some time watching the Susquehanna River and bridge at Rockville, proceeded up the Northern Central and Philadelphia and Erie Railroads, reaching Sunbury at 10 A.M., June 2d, where the water was over the track. The main part of our carpenter force was occupied during the balance of the day loading additional cars with heavy lumber from a raft found in the canal near Northumberland. Leaving the carpenters' train, Vice-President Thomson and myself proceeded and reached Montgomery bridge on the evening of this day, June 2d. It was at once seen that nothing could be done on account of the force of the current and depth of the water. We occupied the carpenters nevertheless at framing caps and top end of logs and sizing the rough stringer logs taken from the canal raft, so we did not move the carpenter trains to the bridge until the following day, June 3d.

The situation at this time was found to be very little improved

as to the falling of the water; four spans of the bridge were gone, the piers washed pretty well down, and the fifth span wrecked so very badly that it was of no use. The piers of the other spans were damaged and not safe to carry the remaining spans of Howe truss without trestling. The water was 27 feet in depth and running so swiftly that we could not sound to the bottom with any appliance we had.

We continued to work, however, "like beavers," and during this day and the day following we used our greatest efforts in framing material to construct our trestle-bridge to cross the river as soon as the water would fall enough to allow, and adding additional material and equipment and commissary department to our forces to make them as strong as possible for a united effort. The difficulty in working in so swift water at this depth can be better imagined when it is understood that an inch gas-pipe was repeatedly broken off by the current in our effort to get the depth by forcing it to the bottom, and when we made the soundings for the first trestle, it was by tying two bars of pig lead together and by making a strong cable of twisted telegraph wire, bracing it to the water line. We thus succeeded in getting to the bottom, not in a straight line, of course, but by making an allowance, it proved reasonably satisfactory to get the proper lengths for the legs of our trestle bents. The bottom of the river was found to be so rocky and uneven that it was necessary to make soundings for each leg of a bent, so as to fit the bottom and make it well enough located to carry the heavy trains. We thus found it a most difficult undertaking, besides we had no labor or material within reach of the north end of the bridge, and but a single track and no sidings at the end at which we were working upon which to shift trains or receive the material we were bringing for the hurried undertaking. On June 4th, the second day of our forces being at the bridge, we were able to get the first bent in place, upon which we spiked 2½ tons of old railroad iron to sink it through the current to the bottom. We had placed our electric car immediately at the south end of the bridge and extended the wires so as to give us light during the night.

During those first two days we had laid nearly two miles of

additional track and sidings with switches for receiving the large amount of material and shifting cars which had to go back and forth.

We had also succeeded in getting a large number of boats, and as soon as the river could be crossed by boatmen, started a method of hauling frame material in wagons about three-quarters of a mile up stream, nailing together a raft at the water's edge and boating it across with a heavy force of boatmen to reach the other side, so as to be able to work from both ends.

The day following, June 5th, the water had fallen until it was seventeen feet in depth, and we were successful in adding to our fleet a small steam ferry-boat discovered in the dam at Northumberland which assisted us very much in ferrying the frame stuff across the river to the north end, at which time we divided our carpenter force and worked from both ends, and can be said to have been fairly under way at this time, daylight of June 5th.

The total length of the bridge of eight spans is 1,242 feet $5\frac{1}{2}$ inches, 1,000 feet of which we trestled = 800 feet continuous + 200 feet in part.

This work was completed and the first train passed over about dusk on Saturday, June 8th. Time of raising the bridge, morning of June 5th, to 8 in the evening of June 8th, three and a half days; progress made, about 300 feet per day.

I would further state, in relation to this, that our standard P. R. R. trestles with wooden stringers usually have 12 feet span, but these trestle bents were placed 15 feet apart, although constructed without a sill. Upon this was turned the very heavy traffic of all main line trains of the P. R. R., which first opened out through this as the only channel, and continued under almost a constant roll of wheels for some weeks until the Juniata bridges were built between Tyrone and Harrisburg, and continued quite satisfactorily until an iron bridge was ordered.

The 15 feet for a span was decided upon to save time, but not until after a serious consideration, and investigation as to the nature of the river bottom. The washed-out spans were 158 feet in length. A 12-foot span would have taken twelve bents for one opening. A 15-foot span would take but nine bents for one opening. We thus saved three bents per one old span of the bridge,

and it would have taken one-third more bents for 12 feet than for 15 feet. Consequently we saved one-third of the time, and opened the road for traffic more than one day earlier by adopting the long-span method.

In a very short time after the traffic was opened, our carpenters had all their tools loaded, and such material as we thought would be worth taking along to be used elsewhere, and we were assembled ready to move westward, which we did, under directions of Mr. Thomson, Vice-President, who had passed on the day previous to Altoona. Leaving Montgomery bridge about 10 o'clock that night we arrived at Tyrone the following morning (Sunday, June 9th), where I received orders to proceed with the entire force to the Pittsburg Division. Arriving at South Fork and the Viaduct in the flooded district along the Conemaugh Valley; we there joined Mr. T. N. Ely's shop force in the reconstruction, and continued until meeting the west of Pittsburg forces under Mr. James McCrea, General Manager, at the trestling of Bridge 6. The western force had rendered us valuable aid by coming from that much isolated end of our P. R. R. Division and constructing the trestle-work at Johnstown and also at Buttermilk Falls, and at Bridge 6, laying the washed-away tracks about Conemaugh and opening the road west of Bridge 6.

The flood in the Conemaugh Valley was found to be of the most serious nature, and as I was left as the field officer in charge of reconstructing the railroad from Johnstown to South Fork for the following two months and a half, I had not the time to preserve as extensive notes and data as I would wish to present to form a complete history. I will add, however, such items as may occur to me or are found within my note-book.

As a general view I have prepared a plan and profile from the South Fork dam westward to beyond Johnstown, which, I think, is of special interest, giving low water and flood line and the grade of the railroad track. This has been prepared with the correct railroad alignment, and actual levels for the flood line and the grade of the railroad. The part of the railroad as washed away is shown on the plan by the heavy dotted line. The sections that remained are shown in two parallel full lines.

I would call attention on the profiles, to the several dams which

were made in the flood as it passed down this valley. First, at the loop (of $1\frac{4}{10}$ miles) at the Viaduct, where, from the crooked line of the stream, the narrow hills and the Viaduct Bridge and embankment, the flood was not able to pass as rapidly as it had at other places, and consequently dammed up to the depth of about ninety feet above the ordinary low water level. Other smaller dams occurred at different points until it reached a similar loop in the river (of $1\frac{2}{10}$ miles) at Bridge 6. Here it dammed to a depth of about forty feet, and after breaking away swept down the valley with increased weight of water and force, striking the villages of East Conemaugh, Franklin, Woodvale, West Conemaugh and Johnstown, and finally ending its force against the hills surrounding three sides of Johnstown and the seven-span stone arch bridge recently constructed by our Railroad Company.

The lineal feet of tracks which we lost in the four running tracks, eliminating sidings and yards at Conemaugh and elsewhere, were slightly over 20 miles between South Fork and Johnstown bridge. This amount of rail was entirely destroyed and had to be replaced by new rail. Not only was the track and roadbed washed away, but the rails were bent, broken and a large percentage lost. The embankments were torn away almost completely from South Fork to Viaduct, a distance of $1\frac{1}{2}$ miles, and at the Big Wash near Bridge 6, where the river reclaimed its old bed, we were compelled at a great expense to put the river back to its former position, making a four-track bank 14 feet to 16 feet in height for about one mile.

At Buttermilk Falls the four-track embankment was completely washed away, and after a temporary trestle was constructed for the opening of the railroad it was filled in by dredged material and shovel-plowed from flat cars.

The tracks at Conemaugh and Woodvale were completely swept away, but the grading was comparatively light and of sand filling, except in the neighborhood of the Conemaugh round house, where the embankment was washed away and had to be replaced by filling 6 feet to 12 feet in depth. At the bluff east of Johnstown about 1,000 feet of four-track embankment was washed away and a height of about 16 feet had to be replaced.

At the east end of Johnstown bridge about 1,000 lineal feet of four-track embankment was washed away; height about 18 feet, and was filled in.

Thus the work progressed until June 14th. Just a fortnight after the flood direct communication was established via the main line, Philadelphia to Pittsburg, and nearly all passenger schedules were re-established and movement of freight traffic resumed with reasonable regularity.

At the end of five weeks from May 31st (the day of the flood), all this two and four-track system of railroad was re-constructed and opened for the traffic with as many running tracks as we had before the flood, excepting, of course, single track gauntlets across high bridges and trestles—all of these were replaced with three-track stone arch bridges as rapidly as practical during this year. A history of these would be interesting, particularly Bridge 6 and the Viaduct.

As to the damage in the Valley, I would state only a few words at this time.

The reservoir at South Fork, at an elevation of about 1,700 feet above sea level, giving away about 3 P.M. May 31st, caused a great amount of water to flow down a narrow valley, falling about 53 feet to the mile. This lake had an area of about 400 acres, which, at its normal level of 60 feet in depth at the breast, contained 3,000,000,000 gallons or 400,000,000 cubic feet of water. The weight of this would be about 11,000,000 long tons. The flood increased this depth to 70 feet at the dam breast and the quantity of water to about 5,000,000,000 gallons or 666,700,000 cubic feet, weighing in round figures 18,000,000 long tons.

By the profile it will be seen that the flood down this valley averaged about 27 feet in depth above ordinary low water. It would seem that this depth of water would not cause so very much damage, when it is compared with other floods, as follows: The Susquehanna River, a body of water very many times as large as this which at this flood was at Williamsport 34 feet above its ordinary level; and the Juniata River, east of the Alleghenies, carrying much more water than this, notwithstanding the flood was 23 feet above its ordinary level; and with the Monongahela River, which has of late years had

floods to 33 feet above its ordinary level. The cause of so much damage in the Conemaugh Valley must be looked for in some other direction than the quantity of water and the height of the flood.

By again referring to the profile of the Conemaugh Valley it is seen that the fall of this river is 53 feet per mile. The fall of the Juniata River is about six (6) feet per mile. The fall of the Susquehanna River past Williamsport is very slight indeed, from $1\frac{7}{10}$ feet to $2\frac{4}{10}$ feet per mile, as also is the Monongahela River, and in this great difference may be found the correct cause of the damage along the Conemaugh Valley.

If a large lake of water is suddenly turned out and reaches a comparatively level and large area it will soon spend its force and do but little damage; but take the same quantity of water by applying this case, weighing 18,000,000 tons, and start it down a narrow gorge or valley falling 53 feet per mile, and at the rate of a mile in four minutes, it can be very easily understood without further detail that so great a falling weight must cause much damage to whatever it comes in contact with in opposition to its course.

DISCUSSION.

Mr. John Birkinbine: It is hard for us to appreciate the tons, the gallons or the cubic feet represented by a flood of water, and it may be of interest to endeavor to estimate these from an area with which we are familiar. One inch of rain falling upon an area of one square mile is equivalent to 2,323,200 cubic feet, or nearly seventeen and a half million gallons, and this quantity of water will weigh 145,200,000 pounds, or 72,600 short tons. If one inch of rain fell over the entire area of the city of Philadelphia, 129 square miles, the quantity of water which would be precipitated would be represented by 2,250,000,000 gallons, or 18,730,000,000 pounds, or 9,365,000 short tons. Therefore the quantity of water represented by one inch of rainfall distributed over twenty-four hours falling upon the area of Philadelphia, would be nearly ten times the maximum pumping capacity of all our water-works engines for a day, and is more than twice the total capacity of all the reservoirs now connected with the city water-

supply; in other words, existing pumping machinery connected with the city water works, if all were active, could deliver in twenty-four hours about as much water as would be represented by a rainfall of one-tenth of an inch over the area of Philadelphia, and five-tenths of an inch falling on the same area would be more than sufficient to fill all our public reservoirs if they were empty.

I have not at hand the data which will give the exact average topography of the area within the city boundaries, but this may be safely assumed at 84 feet; one inch of rain (omitting evaporation and absorption) collected on an area equal to Philadelphia, and falling 84 feet to the rivers would, if applied to motors of average efficiency, produce continuously for twenty-four hours 190 horse-power.

But often our rainstorms are so severe that an inch of rain or over falls in one hour, and the relation between the quantities above mentioned would be magnified twenty-four times, for a downpour precipitating one inch of rain in sixty minutes.

For years I have been interested in a study of the composition of the atmosphere and the work done by the sun in raising the moisture afterwards precipitated as rain. We are told that our earth is surrounded by three practically distinct yet closely associated atmospheres, composed respectively of oxygen, nitrogen and aqueous vapor, the latter being present in an amount approximating 1.5 per cent. of the total atmospheric weight.

We see the volume of water flowing past Philadelphia in its two rivers—some times very low, at other times as freshets—but do we consider that during the year probably four times as much rain has fallen upon the area drained as is represented by the total annual flow?

Some years ago I prepared an article entitled "Sun Pumping," which met with so much favor that a repetition of the general statement applied to the figures above may be useful in the present discussion. Professor Loomis gives the average height of clouds as about two miles, and, as the aqueous vapor always present in the atmosphere is suspended for a considerable time, and carried for great distances by winds, it is highly probable that the great majority of the water which falls as rain has been

elevated by the sun to a height approximating 10,000 feet. While it would be fair to assume this figure in calculations, there may be objection to it on the ground that the clouds from which much of our rain is precipitated are not more than a half mile above the earth, and therefore a height of but 3,000 feet will be estimated for, but those who desire to assume the greater elevation can readily calculate what the figures would be for 10,000 feet. As above shown the weight of one inch of rain upon one square mile is 145,200,000 pounds, multiplying this by 3,000 feet for the height, and dividing by 60 on the assumption that this inch of rain fell in one hour, we have as a result 7,260,000,000 foot-pounds, representing the amount of work done by the sun per minute if the water was raised as rapidly as it fell, this is equivalent to 220,000 horse-power. If pumping machinery worked at the low economy of two pounds of coal per horse-power per hour, or if the pumps gave a duty of 100,000,000 foot-pounds, 200 gross tons of coal would be required to raise to a height of 3,000 feet the water represented by one inch of rain on a square mile; now multiplying this by 129 to represent the area of Philadelphia, we have 28,380,000 horse-power and a coal consumption of 25,800 long tons.

These figures are merely offered as a means of understanding the quantity of water which falls upon a given area, and of forming some conception of the marvelous force constantly and silently at work lifting water in one part of the earth and conveying it for precipitation on another. If we multiply the area of Philadelphia by from ten to sixty to represent the drainage basins of our rivers in Pennsylvania, and augment the rainfall in accordance with the reports of some of our severe storms, the results will be even more startling, and the wonder will be that the damage by freshet is not even greater than that recorded.

Mr. Amasa Ely: While Mr. Birkinbine's rainfall value of 1 inch per hour is a high one, it is not a very unusual nor a maximum one. I remember that some years ago (about August, 1886, I think), there was a fall of an inch and a half in Philadelphia, in twenty minutes.

Mr. J. Chester Wilson: The rainfall figures which I gave in my paper on the "Old Viaduct Bridge Over the Conemaugh" were based upon a report prepared by Mr. Lorin Blodgett, from

which the map was made that I showed at that time. This report confirms statements that were made respecting the excessive rainfall in the middle and western part of the State. The American Society of Civil Engineers, shortly after the Johnstown disaster, published a very complete report, with illustrations, and pointed out that the excessive rainfall from the adjacent territory, as well as the bursting of the dam, was responsible for the damage that occurred.

Mr. Birkinbine: The damage at Johnstown was directly due to the breaking of the South Fork Dam, but the valleys of the Juniata and the Susquehanna Rivers were seriously damaged by an absolute flood.

Mr. Robert A. Cummings: Have there been any experiments made in Philadelphia to determine the proportion of rainfall that drains off in this district?

Mr. Amasa Ely: In 1885 an experiment was made to determine this fact by preparing two sets of slopes with diamond-shaped areas of sodded, plowed and wooded ground, from which the rainfall that ran off was collected and measurd. The amount of run-off varied, if I remember rightly, from 15 to 60 per cent. of the rainfall. An average territory in this vicinity would show, I think, about a 50 per cent. run-off. In Great Britain I think the average is 40 per cent.

Mr. James Christie: Ten or fifteen years ago a friend of mine, in western Kansas, made a similar set of experiments to test his theory that the amount of arable land in the West followed the use of the plow. I remember, also, that after the French Commissioners had examined the Isthmus in considering the Panama Canal there was an immense rainfall that nearly covered the entire neck. We know that, as far back as the times of the ancient Egyptians, people have taken advantage of the flood-rains to store up a supply of water in reservoirs which could be afterwards used in the dry season. I believe that, recently, Congress has made an appropriation to experiment on storing the water of the upper tributaries of the Mississippi, with a view to preventing the disastrous floods which occur along its southern banks.

Mr. Birkinbine: I think that the storage work thus far done by the Government has been more for the purpose of supplying

water during the dry season to aid navigation between St. Louis and St. Paul. I think Western irrigation might help much by water stored in large resorvoirs.

Captain C. D. Dahlgren: Although we certainly have some very severe storms in this country, I concluded, after eight years passed in Mexico, that we know very little about really heavy rainfall. The rainy season there begins regularly on a certain day in June at about one o'clock, and the rain often comes down in sheets or "bucketfuls," as we say. The towns are built back from the streams beyond the reach of the water, which sometimes rises as much as 40 feet in an hour and a half, carrying huge bowlders down in the rushing torrent. The storms are generally accompanied by dreadful lightning and thunder.

Mr. Max Livingston: I think that the conditions above stated have changed somewhat in recent years, as a friend of mine, now in Mexico, complains that they have been suffering lately from lack of rain.

Mr. John E. Codman: Regarding the rainfall previous to the floods of June, 1889, I would say that up to May 20th, it was about 3 to 4 inches below the average, but after that date the fall was very great, quite similar to our recent experience in all respects, except that the storm of the last few days passed off in a more easterly direction. I agree with Mr. Richards that the damage in the Conemaugh Valley was undoubtedly due to the bursting of the dam, and the rush of such an immense volume of water down so steep a slope, rather than to previous rainfall.

Comparisons of the observations show that the volume of water in our streams is very nearly the same as it was sixty years ago, and has apparently not been affected by the destruction of the forests, but this volume flows off the rainshed much more rapidly than before our trees were cut down, and consequently causes alternate freshets and droughts. Although the freshets which occur in May or June vary in their character, river men always look for a June rise. It occurred this year considerably earlier than in 1889.

Regarding our recent rainfall, the following data may be of interest. On May 20th and 21st, 5.13 inches fell at Philadelphia. Beginning in the early morning of the 20th, 1.60 inches fell up

to 8 P.M., and from then to the same hour on the 21st, 3.25 inches. The next heavy pour was on the 28th at 2 P.M., when .85 inches fell in twenty minutes. On the Perkiomen at Spring Mount, 6.29 inches fell in forty-nine hours and twenty minutes. At the forks of the Neshaminy, about the same distance (30 miles) away, there was an almost continuous and regular downpour for fifty-four hours and ten minutes, amounting to 5.71 inches.

The heaviest rain on record was on June 6, 1893, at 2 P.M., when 1.20 inches fell in twelve minutes, or at a rate of 6 inches per hour.

The following data for the storm of May 20th and 21st may also be of interest. The total fall at Quakertown was 15.02 inches, at Germantown, 11.97 inches, and at Pottstown, 12.26 inches. The Neshaminy rose 16.27 feet, the Perkiomen 17 feet and the Tohickon 13.05.

MR. L. Y. SCHERMERHORN: A fact which to my mind has not received sufficient attention is, that the direction from which the rain comes has very much to do with torrential floods. The storm of 1889, in the upper Susquehanna valley, moved from southwest to northeast, and consequently followed the direction of the stream, and lasted for about thirty to thirty-six hours, so that about twenty hours after the commencement it had reached maximum flood at Williamsport, the freshet volume and the rainfall flowing down together.

Regarding deforestation, while the annual rainfall remains about the same, where everything is removed from the ground which would hold rain or retard its run-off, it quickly flows into the streams, and increases the volume so greatly and suddenly as to cause dangerous freshets and floods. In France, especially along the Loire, they are changing these conditions, so as to hinder the flow-off, one of the most effective means being the use of rough artificial dams in the affluent streams.

MR. EDWIN F. SMITH: It has been observed that floods always follow periods of drought. Regarding extremes, the flow-off observations over a considerable period and area in this State have shown the minimum run-off to be 0.15 cubic feet per second per square mile, and the maximum 70 cubic feet per second per square mile. A rainfall of 11 or 12 inches, distributed over a period of

forty-eight hours, is an average condition for maximum floods. Although many of our oldest inhabitants attribute the floods of 1850, in the Schuylkill valley, to the failure of Tumbling Run dam, records show that the dam did not break until some time after the worst damage had been done. This flood followed a rainfall of 12½ inches in twenty-four hours.

Mr. Amasa Ely: Will Mr. Richards kindly tell us what is his opinion as to the real cause of failure of the South Fork dam?

Mr. Richards: A committee of the American Society of Civil Engineers examined into this matter very thoroughly a short time after the Johnstown flood, but they have never presented, so far as I know, a very clear report as to their conclusions.

XVI.

THE ENGINEERING FEATURES OF THE HARRISON BUILDINGS AT TENTH AND MARKET AND TENTH AND FILBERT STREETS.

By W. Copeland Furber, Active Member of the Club.

Read, June 16, 1894.

In presenting a paper under this heading to the members of the Engineers' Club, it must necessarily be an outline or general description of the work, and not a detailed summary of all the factors which enter into its design and construction, and perhaps might be prefaced with a short descriptive outline of the growth of the construction of skeleton buildings.

The skeleton construction of the modern large building is not by any means a new idea, excepting, perhaps, in its careful calculation and adaptation of means to an end. Such construction has been a gradual and constant development. The first use of it in a primary way which occurs to me, was in some of the European countries, particularly in England, where it was quite common to build houses of a frame of wood. The spaces between such framework were afterward filled in brick and then plastered inside and out. In business architecture the use of a long beam or lintel, resting on piers or cast columns at intervals of say 18 to 25 feet over the first story, depending somewhat on the frontage of the lot, leaving a large open space with few obstructions to light and doorways, was followed by treating the second story and upper stories in a similar manner. The stability of this construction depended frequently upon adjoining brick walls, which provided lateral stiffness lacking in the iron front. As business property increased in value and the necessity of light and air was recognized, and the advantages of concentrated heating, lighting and power plants were demonstrated, it was natural that with the easy means of ascent and descent permitted by the perfection of hydraulic elevators, buildings should be designed with more stories than had been considered desirable. With increased

height, of course, came increased weight of walls and floors. With ordinary masonry construction the space demanded by the supporting piers and walls became so great that it was found prohibitive. As brick piers had been superseded in the front walls of many buildings by iron construction, the next step was to substitute iron for brick in other places; and so the gradual use of material of high resistance in place of the usual brick and masonry construction might be traced to the present complex office buildings or hotels.

At first cast iron was used, but in many places the difficulty of making proper connections, and the growing distrust of cast iron as a reliable material, coupled with the constantly decreasing price of wrought iron and steel, has resulted in the use almost exclusively of wrought steel in skeleton construction.

There are many types of the composite buildings composed of masonry, terra cotta and steel. In the most common type the walls, floors, and in fact all the loads in the building, including in many cases pavement loads, are borne entirely by the columns, as in the Harrison Building at Tenth and Market Streets.

In some other types the walls are supported on their own footings, and the columns carry the floor-loads only.

Frequently the two types are combined for various reasons in the same buildings, as in the Harrison Stores at Tenth and Filbert Streets.

The architectural design largely influences the particular types of construction used.

When the building is not unduly high, and deep reveals in the window openings with ample wall space is demanded, the self-supporting wall, or the wall carried on plate girders at one of the lower stories, and supported at intervals of convenient lengths, is probably the best design, as in the Filbert Street building on the Filbert and Tenth Streets fronts.

With the increasing height of buildings come new forces, or forces having destructive tendencies, as wind and vibration, which must be considered in the design of the framework. If the building is wide in proportion to its height, and is protected and assisted by adjoining buildings, wind bracing is unnecessary; but if the building is isolated and narrow, it is absolutely essen-

tial. The wind bracing used in buildings sometimes is merely deeper floor beams on column lines, increasing the inertia of the joints. Frequently, also, knee braces are used; both of these devices, however, bring a bending on the columns, but it is often the only devise left the structural designer. The use of the portals or portal bracing is the next best thing, and under certain conditions forms a satisfactory compromise between simplicity of construction and utilitarian requirements in the arrangement of doors and windows through walls and partitions. Where it is possible the use of sway bracing or diagonal tension and compression members between floor systems on lines of column centres, forms the most direct and simple method.

Many architectural designers depreciate the use of wind bracing as useless and unnecessary, basing their objections on the stability of brick walls, etc. It must be borne in mind, however, that while the walls resting on their own footings use their own tenacity and gravity in resisting destructive forces, the skeleton building has only the resistance of the joints of its columns and beams, the number of which is necessarily few.

The Harrison Building, at Tenth and Market Streets, is a curtain wall structure carrying everything on its columns on three sides, the party wall is of brick masonry and supports the floor adjacent to it.

The columns are about 21 feet centers, and are of the Phœnix pattern. The curtain girders are of rolled beams, with top and bottom cover plates. The interior girders are 24-inch built beams. The attachment of the girders to the columns is by means of the pintle plate, which is simply a plate set between the sections of the columns on its diameter. The pintle plate is riveted to the web of the beam.

The subordinate beams are of wood, Georgia pine, and the floor is 3-inch spruce with 1-inch maple finish floor. The floors have asbestos and water-proof linings between the rough and finish floor.

The unit strains used were for columns 13,000 — 20 $\frac{l}{r}$; rolled beams, 16,000; for built sections of beams, 13,000; for wood,

1,500; for brick masonry, 150 pounds per square inch. The floors were calculated for 200 pounds live load, the girders for 85 per cent. of this, and the columns for 75 per cent. in addition to its dead load.

The brick piers supporting the columns are on concrete footings, with blue-stone capstones directly under the columns. The footings were carried down to water gravel, which was found at about 20 feet below the pavement, or at + 15.0 feet City datum.

The footings are proportioned for a total load on the ground of not exceeding four tons per square foot. There has been no settlement perceptible in any part of this structure.

The curtain walls are of dark brown Pompeian glazed brick and the terra cotta work of the same material, backed with common brick. The entire work is laid in cement with a small addition of lime. American and German cements were used after careful testing. The cornice is supported by cantilevers and the roof is covered with tin.

Architecturally, the style of the building is in Italian renaissance, which seems to lend itself suitably to commercial structures. The lot on which the building stands is 65 x 200 feet.

The following approximate amounts of materials were used in the building:

225 yards of concrete,
950 yards of stone masonry,
1,250,000 bricks.

Lumber.

190,000 feet b. m. of yellow pine stringers,
350,000 feet b. m. hemlock 2 x 3 inch stuff,
105,000 feet b. m. maple floorings,
12,000 casings for iron beams,
100 scaffolding.

1,500 tons of structural steel.

Messrs. Cope & Stewardson were the architects.

Mr. Lewis Havens, the general contractor.

The Phœnix Iron Co., contractors for structural work.

The Harrison stores, at the corner of Tenth and Filbert Streets, now occupy the site of the old Massey brewery. The dimensions of the building are 308 x 137 feet. The old cellar was of varying depths, varying from + 26 to + 8 feet City datum. The

curb is about 35 feet. The underlying supporting ground was compact water gravel, as in the Market Street building, and no trouble was experienced in the foundations. On account of the deep foundation piers, required by reason of the great depth of the old cellars, and the cost of brick masonry and stone capstone, and of the time allowed for construction, it was decided to use concrete. The concrete was required to be of the following composition:

Cement—

Portland, of American or foreign manufacture,

Fineness, 100 per cent., through a No. 75, having 5,600 meshes per square inch.

95 per cent., through a No. 100, having 10,000 meshes per square inch,

75 per cent., through a No. 200, having 40,000 meshes per square inch,

Must satisfactorily pass the boiling test,

Tensile strength neat 7 days, 450 lbs. 28 days, 600 lbs. 3 months, 700 lbs., with three parts of sand and one of cement, 7 days, 125 lbs. 28 days, 200 lbs.

The cement must also show a progressive strength.

Concrete—

One part Portland cement, to three parts of coarse, tide-washed bar sand, entirely free from mud or foreign material; Bordentown sand is not to be used,

Five parts of crushed rock, free from dust, such as will pass through a 2-inch ring, and be retained on $\frac{1}{4}$-inch rings; at least 40 per cent. of the rock shall be fine stuff.

The sand and cement to be carefully measured, and after being thoroughly mixed with a hoe and rake on a tight platform, shall be shoveled through a fine sand screen onto an adjoining platform, to permit a thorough mixing of the sand and cement and insure a homogeneous product. The rock, after being washed, shall be added, and water shall then be applied with a rose nozzle; only sufficient water shall be used to thoroughly dampen the mass. The whole batch shall be turned over and fully mixed. Sufficient concrete must be made up rapidly, and at one time, to fill one layer to its proper height, so that the initial set of any layer shall not be disturbed by subsequent ramming. The courses of concrete shall be generally about 18 inches. It shall be put into wooden frames of sufficient strength to resist the ramming. The rammer to weigh not

less than 50 pounds, and to be constantly used until the layer is finished.

The concrete piers were very satisfactory, some of them being 20 feet in height. They were designed so as to load the bearing ground at 4 tons per square foot. The piers were made square in area, and the tops of the piers were designed to receive a load of 200 pounds per square inch from the columns. The bearing plates of the columns were of cast iron, and were designed to carry all the load on their perimeters.

The same unit stresses were used as in the Market Street building. The columns were of the channel and plate section. The interior main girders were 24-inch rolled beams. The joists are of 2 × 10 Georgia pine. The floors of 1-inch hemlock and 1-inch finish-floor of maple.

In this building the main columns support the floors, the brick wall above the sixth floor and the thin 9-inch walls in the rear. The main wall on the Filbert and Tenth Streets fronts is carried by a plate girder 30 inches deep at the second floor line and supported by a Z-bar column under each end, and is independent of the main structure. This method of carrying the walls is believed to be very good for such buildings as this, as it allows the structural work to be erected rapidly, and dispenses with heavy curtain girders in the upper stories. The cornice of this building is carried by longitudinal beams supported by cantilevers at the column centers.

The following approximate amounts of materials were used in the construction of the building: 260,000 Pompeian brick; 2,700,000 common brick; 590,000 feet yellow pine joists; 340,000 feet hemlock flooring; 290,000 feet maple flooring; 106,000 feet 2-inch hemlock roofing; 250,000 feet Neponset paper; 250,000 feet asbestos paper; 1,900 tons of structural steel; 1,880 yards of concrete; 1,660 yards of stone masonry; 12,900 yards of excavations.

The architects of the building were Messrs. Cope & Stewardson; the general contractors, Wm. C. McPherson & Son; the contractors for brickwork, Franklin M. Harris & Co.; the contractors for structural steel, Carnegie & Co.; the shop work and erection, Edge Moor Bridge Works; the contractors for cement, Coplay Cement Co.

NOTES AND COMMUNICATIONS.

THE QUADRICYCLE PEUGEOT.

At the meeting of June 2, 1894, Mr. A. E. Lehman contributed the following :

The *Quadricycle Peugeot* or petroleum velocipede consists of a four-wheeled vehicle, the principal features of which are a hollow frame, bicycle wheels and a combustion chamber. The frame is composed of cold drawn steel tubing, its hollow spaces being used as a reservoir to contain water intended to cool the combustion chamber.

The wheels are constructed on the plan of the best bicycle wheels, having a metallic felloe, encircled by a pneumatic rubber tire. The wheels revolve on ball-bearings, each wheel independent of the other and propelled by sproket gearing and chain.

The running gear is so arranged as to provide a differential movement, the front wheels controlling the direction of the quadricycle and also supporting the carriage in such manner as to so equalize the vertical and lateral motion, that each wheel may revolve freely within the circle it describes, thereby contributing to the easy and comfortable motion of the vehicle.

The fuel employed is "essence of petroleum" contained in a recipient termed a carburatem, where it is volatilized before entering the cylinders. Here an explosion is produced by two burners of platinum shut in a zinc "envelope" resembling the form of a lantern. The carburatem contains four litres of fluid, sufficient for a journey of three hours or forty-five kilometers. A reservoir for a larger supply of petroleum placed in tanks under the seats, is sufficient to run the conveyance twenty hours or about 300 kilometers. The supply of water carried in the hollow frames will last five hours, equivalent to a run of eighty kilometers.

The motor is of the Damelair system and exerts a force of two-horse power, sufficient to obtain, on a good road, a speed of about fourteen miles per hour, the carriage containing four persons of 150 pounds weight each. The machine will overcome grades of 10 per cent. with this load and 15 per cent. carrying two persons or 300 pounds.

The force of the motor is not variable excepting for four different rates of speed, respectively, 5, 10, 14 and 18 kilometers per hour. It is with the former speed that grades of 10 per cent. can be ascended. The speed is under perfect control of the driver and can be instantly changed without any jerking or unpleasant movement in the conveyance.

Only four minutes are required to develop power. On starting the movement is quite gradual, but soon increases and at full speed the carriage may be stopped promptly by a brake, which, when put in operation, automatically shuts off the power.

The motor is tightly encased and all working parts properly protected from dust and dirt.

The length of the carriage is eight feet; weight, 1,000 pounds; diameter of driving wheels, forty inches. The carriage can turn within eighteen feet.

This motor has performed a journey of 2,200 kilometers, between Valentigney and Brest, France, via Paris, in 140 hours of running time; at an expense of one cent per kilometer. No perceptible wear and tear resulted.

The most striking features of the machine, as a whole, are its graceful outlines and ease of movement, and a very important advantage is in the fuel used, being so easily and generally obtainable in all parts of the world.

It may be said that for land transportation this machine is what the most improved naptha launch is to transportation by water.

ABSTRACT OF MINUTES OF THE CLUB.

Business Meeting, April 7, 1894.—President John C. Trautwine, Jr., in the chair. One hundred and eighteen members and visitors present.

The Tellers reported that eighty-seven legal votes had been cast, and the following gentlemen elected to active membership: Messrs. Ira A. Shaler, Thomas H. Mirkil, Jr., H. M. Norris, Edward V. Maitland, Clayton W. Pike, William C. L. Eglin, C. B. Dahlgren, Stacy W. Kapp, Edwin F. Miller, Herbert G. Geer, James C. Hallsted and Josiah Harmer.

The Secretary read a communication, addressed to the President, from Mr. Albert Lucius, in which he comments on the recent discussion of the above subject, expressing the opinion that for such plate-girders as those required for usual railroad bridges, web-shears measured by the end-reaction should not exceed 4,000 pounds per square inch, and web-plates should not be thinner than $\frac{3}{8}$ inch. The use and position of stiffeners, web-splices and rivets was also commented upon, and Mr. Lucius stated that, in his opinion, chord-stresses might safely be taken at 12,000 pounds, excepting for short spans and stringers, where 9,000 to 10,000 pounds are enough.

Mr. Emile Geyelin read a paper on "The Baptism of the Great Niagara Tunnel."

Mr. E. M. Cook read a paper on "Methods and Apparatus for Drying with Heated Air."

The Secretary announced the death of Captain Spencer C. McCorkle, Active Member of the Club, which occurred on March 20, 1894, and also read a memorial prepared by Superintendent T. C. Mendenhall, of the United States Coast and Geodetic Survey. Upon motion, the President was directed to appoint a committee to prepare a suitable memorial for the Club.

Regular Meeting, April 21, 1894.—President John C. Trautwine, Jr., in the chair. Seventy-eight members and visitors present.

The President announced the unavoidable absence of the Secretary, Prof. L. F. Rondinella, and requested Mr. Strickland L. Kneass to act as Secretary *pro tem.*

Mr. A. Falkenau presented a paper on "The First United States Pneumatic Postal System." The subject was discussed by Mr. W. W. Carr, Postmaster of Philadelphia; Mr. John Field, ex-Postmaster of Philadelphia; Mr. W. J. Kelly, President of the Pneumatic Transit Company, and Mr. B. C. Batcheller.

The President announced that the Club had been invited to attend a special meeting of the Electrical Section of the Franklin Institute on April 24, 1894.

Regular Meeting, May 5, 1894.—President John C. Trautwine, Jr., in the chair. Sixty-seven members and visitors present.

The President called attention to the pipe-end sections of pneumatic postal tube, which were presented to the Club by Mr. A. Falkenau at the last meeting, and expressed the thanks of the Club for this interesting and well-mounted gift.

The President also announced that Mr. Howard Murphy had been appointed a committee of one to prepare a memorial upon the late Captain Spencer C. McCorkle, and requested those having information with regard to the life and works of the latter, to communicate with Mr. Murphy.

Since the meeting of April 7th, when the announcement was made that the Board had extended an invitation to the American Institute of Electrical Engineers to use the Club House for headquarters during their convention to be held in this city from the 15th to the 18th inst., it has been decided to tender a reception to visiting members by the Engineers and Manufacturers of Philadelphia, under the auspices of the Club and the Electrical Section of the Franklin Institute.

The Secretary read a letter of thanks from the English Society of Engineers for the reception extended to them by the allied societies of the United States and Canada at the World's Fair in Chicago, which had been transmitted by Mr. O. Chanute, President General Committee Engineering Societies Columbian Exposition.

The Secretary also read an invitation received from the American Institute of Electrical Engineers to attend their Eleventh Annual Meeting on May 15th, 16th, 17th and 18th, in the hall of the Club House.

As Mr. Joseph T. Richards was unable to be present, his paper on "Rebuilding the Pennsylvania Railroad after the June Flood of 1889" was postponed, but at the call of the chair a discussion on "Rainfall and Floods" took place, the participants being Messrs. John Birkinbine, Amasa Ely, J. Chester Wilson, Robert A. Cummings, Max Livingston, James Christie and Capt. C. B. Dahlgren.

The Secretary read a paper prepared by Mr. A. L. Eltonhead, on "The Electro-Metallurgy of Gold and Silver." The subject was discussed by Capt. C. B. Dahlgren and Dr. H. M. Chance.

Mr. Birkinbine called attention to the necessity for thoroughly examining steam engines which have passed through a fire before adjusting the insurance losses. In a recent case, after the damaged engine had been examined, in drawing out the piston a piece of iron weighing about 4 pounds was found to have cracked out of the inside of the cylinder. It was underneath the meeting-point of two ribs that supported the valve-seat, and there was probably a weak spot in the casting, from which the heat caused the iron to crack out.

Mr. John C. Trautwine, Jr., called attention to a table which had been prepared and sent to him by Mr. William A. Pratt, Division Engineer of the Baltimore and Ohio Railroad. It gives the degrees of curve, corresponding radius in feet, number of 30-foot rails in arc between tangents, length of the arc, length of its chord and the central angle, arranged in convenient form to be used in the field. A few of the values were placed on the blackboard to show the arrangement, and the table elicited some discussion on the use of the spiral and other transition curves.

Business Meeting, May 19, 1894.—President John C. Trautwine, Jr., in the chair. Eighty-three members and visitors present.

The Tellers reported that at the election held on this date, the following were elected to active membership: Messrs. Hugh T. Downing, Joseph Kemper, Charles Longstreth, Mason Delano Pratt, Thomas Spencer and Thomas P. Lonsdale; also Mr. George L. Harvey to associate membership.

The resignation of Mr. Robert L. Holliday from active membership was presented and accepted.

Mr. L. Y. Schermerhorn read a paper on "Notes on the Improvement of the Delaware River at Philadelphia." The subject was discussed by Messrs. John Birkinbine, C. L. Prince, Robert A. Cummings and John C. Trautwine, Jr.

The President stated that Mr. Schermerhorn had decided to further illustrate his paper with an object-lesson in the form of an excursion on the Delaware River, on the afternoon of Monday, 21st inst., on a steamboat starting from Walnut Street wharf at 12.30 P.M., and that those members who would like to join the party at that time could do so by notifying the Secretary.

REGULAR MEETING, June 2, 1894.—President John C. Trautwine, Jr., in the chair. Seventy-eight members and visitors present.

The Secretary stated that there were still on hand for distribution to members a considerable number of copies of a descriptive catalogue of the collection of albums, memoirs and designs exhibited at the World's Fair by the Society of Portuguese Civil Engineers.

A communication was read from a Special Committee of three, appointed by resolution of the American Institute of Electrical Engineers, conveying to the Club the thanks of the Institute for the great hospitality and kindness shown to it and its members during the sessions of its recent Annual Meeting, and expressing grateful remembrance of the courtesies extended during that period. This was accompanied by a copy of the resolution for the appointment of the committee.

The President announced that although the excursion planned for the afternoon of May 21st had been postponed on account of the inclemency of the weather, Mr. Schermerhorn hoped to arrange at a later date for the exhibition of the progress of the work being done for improving the channel of the Delaware River.

Mr. Joseph T. Richards read a paper on "Rebuilding the Pennsylvania Railroad after the June Flood of 1889." The subject was discussed by Messrs. John E. Codman, L. Y. Schermerhorn, Edwin F. Smith and Amasa Ely.

Mr. A. E. Lehman exhibited a lantern picture of a road carriage, which he had examined at the makers in France.

REGULAR MEETING, June 16, 1894.—President John C. Trautwine, Jr., in the chair. Sixty-eight members and visitors present.

The Secretary called attention to the Bulletin of the Sixth International Inland Navigation Congress to be held at The Hague during July, which had been received from the Secretary of the American Society of Civil Engineers and posted on the Bulletin Board.

Mr. James Christie reported for the Trustees, that there was now in the Sinkine Fund about $400, which was more than enough to pay a second dividend of 25 per cent. on the two-year notes against the Club, but as most of the holders of these notes had objected to receiving payment in such small amounts, the Trustees had decided to pay off in full the notes of any who felt that they needed the money at this time, and if any such will send their notes to the Secretary's office, check will be sent them or the balance due.

Mr. W. C. Furber gave a very full description of "The Engineering Features of the Harrison Buildings," illustrating his remarks with large drawings of the buildings, and details of their construction and ornamentation.

Mr. Benjamin Franklin read a discussion of Mr. Schermerhorn's paper on "The Improvement of the Delaware River at Philadelphia," which was presented at the Club meeting of May 19th, prefacing his remarks by explaining that the discussion was prepared jointly by Prof. Haupt and himself.

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

Special Meeting, April 7, 1894.—Present: President John C. Trautwine, Jr., Vice-President James Christie, Directors W. B. Riegner, John L. Gill, Jr., Edward K. Landis, Silas G. Comfort, Charles L. Prince, and the Secretary.

The meeting was called at the request of the chair, to consider the advisability of inviting the American Institute of Electrical Engineers to use the Club House for headquarters, and for holding their meetings during their Convention in this city on May 15th and 16th. Mr. Christie moved that the President be instructed to extend such an invitation from the Board to the Institute. Carried.

The meeting then adjourned to attend the Club meeting, and afterward reassembled with Mr. Willyoung, by invitation, who explained that, as a member of the Club and also as Chairman of the Committee on Arrangements for the reception of the American Institute of Electrical Engineers, he considered the plan proposed—to extend the use of the Club House to the latter body—would be advantageous to both societies.

He also suggested for consideration the advisability of the Club's extending a reception to members of the visiting Society on one of the two evenings that they would be in the city, and thought it likely that the Electrical Section of the Franklin Institute would be glad to join with the Club in defraying the expenses of such entertainment. Upon motion it was decided that this matter be taken up again for action at the next regular meeting of the Board.

Regular Meeting, April 21, 1894.—Present: President John C. Trautwine, Jr., Vice-President A. Falkenau, Directors W. B. Riegner, Edward K. Landis, John L. Gill, Jr., Silas G. Comfort, Charles L. Prince and the Treasurer.

In the unavoidable absence of the Secretary, Mr. George T. Gwilliam was appointed Secretary *pro tem.*

A letter was read from Mr. Elmer G. Willyoung, dated 19th inst., accepting with thanks the freedom of the Club House, on behalf of the American Institute of Electrical Engineers, for their coming Annual Meeting.

The Treasurer's Report showed:

Balance from February	$894 30	
Amount received during March	827 65	
		$1,721 95
Amount expended during March		440 01
Balance March 31st		$1,281 94

Professor Comfort moved that the matter of publishing the General Index of Proceedings be laid over until fall. This was amended by Mr. Gill to read that the Index be accepted and filed, the thanks of the Board extended to the compilers, and the matter of its publication be laid over until fall. Carried.

It was moved and carried that a committee of three be appointed by the Chair to consider the subject of facilitating the employment of members of the Club. The chair appointed Messrs. Comfort, Gill and Prince.

Special Meeting, April 25, 1894.—Present: President John C. Trautwine, Jr., Vice-President A. Falkenau, Directors John L. Gill, Jr., Edward K. Landis, Silas G. Comfort, Henry J. Hartley, the Secretary and the Treasurer.

The meeting was called by the Chair to receive a report from a Special Committee consisting of members of the Club, who were also members of the Electrical Section of the Franklin Institute, Mr. Elmer G. Willyoung, chairman.

At the invitation of the Chair, Mr. Willyoung explained that his committee considered that it would be very desirable for the Club to extend a reception to members of the American Institute of Electrical Engineers during their stay in this city at the time of their coming Annual Meeting, and that the Electrical Section would join with the Club in bearing the necessary expenses, either out of the treasuries of the two organizations, or by personal subscriptions. After a discussion of the question it was decided that the reception be held, but that the expenses be met by contributions from individual members.

Special Meeting, May 8, 1894.—Present: President John C. Trautwine, Jr., Vice-President A. Falkenau, Directors Henry J. Hartley, John L. Gill, Jr., W. B. Riegner, Edward K. Landis and Silas G. Comfort.

In the absence of the Secretary, Prof. Comfort was appointed Secretary *pro tem.*

Prof. Comfort moved that a committee of five be appointed to co-operate with a committee of five from the Electrical Section of the Franklin Institute, to take charge of a reception to be tendered to the American Institute of Electrical Engineers, and that Mr. Falkenau be Chairman of this Committee, the other four members to be appointed by the Chairman. Carried. Mr. Falkenau appointed Messrs. Gill, Birkinbine, Landis and Loss.

Mr. Riegner moved that the House Committee be authorized to purchase frames for presidents' portraits, the frames to be as near like those on hand as possible. Carried.

Regular Meeting, May 19, 1894.—Present: President John C. Trautwine, Jr., Vice-President A. Falkenau, Directors W. B. Riegner, John L. Gill, Jr., Edward K. Landis, Silas G. Comfort, Charles L. Prince and the Secretary.

The President reported that in accordance with the arrangements made by the joint committees of the Club and the Electrical Section of the Franklin Institute, a Reception had been tendered to visiting members of the American Institute of Electrical Engineers, on the evening of May 15th, and that from all expressions of opinion, the members of the visiting Society had been very much pleased with the courtesies extended to them in this way, and with the use of the Club House.

The President also reported that the Proceedings of the Sixth International Congress on Internal Navigation, which meets at The Hague in June, will be printed in English if at least 200 subscriptions to the amount of $5.00 each can be obtained. The Secretary was instructed to insert this announcement in the notice for the next meeting.

The Treasurer's Report showed :

Balance from March	$1,281 94	
Amount received during April	633 35	
		$1,915 29
Amount expended during April		1,063 96
Balance April 30th		$851 33

The Secretary presented the resignation from active membership of Mr. Robert L. Holliday, with a statement from the Treasurer that he was in no wise indebted to the Club. The resignation was ordered to be presented at the evening meeting of the Club.

Attention was also called to the fact that Mr. John W. Cloud's resignation of January 2d had not yet been acted upon, pending the report of the committee that had been appointed to request Mr. Cloud to remain in the Club. The Chair explained that the committee's delay was due to the absence of one of its members, for whose signature the letter to Mr. Cloud had been kept waiting, and after some discussion he was requested to have the letter sent off, with two signatures, without further delay.

The special committee on devising means for assisting unemployed members of the Club in obtaining positions, reported that the only method that they were able to suggest was the insertion of notices in our Bulletin of Meetings, announcing that certain positions were vacant, or that members desired employment in certain capacities. There was considerable discussion on this subject, and afterward, upon motion, the report was received and laid over for action.

The House Committee reported that several magazines had been taken from the Club parlor, and that the room was used frequently by non-members. The Committee suggested that the front door be kept locked, and that members be supplied with keys upon deposit of their value, or be admitted by presenting their business or visiting card. Upon motion, this was ordered to go into effect on the 21st inst., and the Secretary was instructed to announce the fact at the meeting of this date, and also to insert a notice of the same in the Bulletin for the next meeting.

Regular Meeting, June 16, 1894.—Present: President, John C. Trautwine, Jr., Vice-Presidents James Christie and A. Falkenau, Directors W. B. Riegner, John L. Gill, Jr., Silas G. Comfort, Charles L. Prince, the Secretary and the Treasurer.

The Treasurer's Report showed:

Balance from April	$851 33	
Amount received during May	434 80	
		$1,286 13
Amount expended during May		444 71
Balance May 31st,		$841 42

Upon motion, the House Committee was authorized to renew the Club's subscription to "The Official Railway Guide," and to order a periodical case in accordance with estimate presented.

The Finance Committee reported that all bills received to June 1st had been approved and ordered paid, amounting to $342.35, which would leave an actual balance on hand at this date of $621.37.

The Information Committee reported the programme for the Club Excursion to Reading on June 30th, and stated that from the replies already received, and other indications, they believed the excursion would be a great success.

Upon motion, the Secretary was instructed to issue with the Bulletin of Meetings a notice of any applications received for employment or assistants, since the previous meeting, said notices to be numbered *seriatim* and inserted but once.

PROCEEDINGS

OF THE

ENGINEERS' CLUB OF PHILADELPHIA

ORGANIZED DECEMBER 17, 1877.

NOTE.—The Club, as a body, is not responsible for the statements and opinions advanced in its publications.

Vol. XI.] NOVEMBER, 1894. [No. 4.

XII.

THE ELECTRO-METALLURGY OF GOLD AND SILVER.

BY A. L. ELTONHEAD, Active Member of the Club.

Read, May 5, 1894.

I HOPE the following will be of interest to some of the members of this club and to others who are interested in the utilization of electricity in the cheaper methods of extracting gold and silver from their ores.

Those who are familiar with the cyanide process know of the difficulties one contends with in using zinc shavings or zinc in any other form to precipitate the gold and silver from cyanide solutions; such as the dissolving of the zinc as the solution passes over it, and after a short time rendering the solution inert for the dissolving of gold and silver, which makes necessary the running to waste of large quantities of solution which contain considerable free cyanide of potassium, gold and silver.

There are certain unaccountable reactions that occur which prevent the total precipitation of the precious metals from the solution when using zinc shavings as the precipitant.

Large losses occur in collecting, drying and smelting the resultant "zinc slimes," or precipitate, which we all know is not

a homogeneous mass, and great care is necessary in sampling it for assay. The resultant bullion is sold in South Africa for about ten shillings ($2.40) less per ounce than for the bullion received from the amalgamated plates of the stamp mills.

There has been erected a small plant for working what is known as the electro-chemical process (patent applied for) on the west side mine of the Tombstone Mill and Mining Company, of Tombstone, Arizona.

The process overcomes the above difficulties encountered in precipitation, in which electricity enters as a factor and the resultant precipitate is recovered in the shape of gold and silver amalgam.

Electricity is being utilized more and more every day in chemical and metallurgical operations, and it is not surprising that an important discovery has been recently made, in which it has been found that the precious metals can be precipitated on a large working basis when they are in solution with certain chemicals such as the cyanides, with the aid of electricity for the electrolysis of certain saturated solutions of the alkaline metals or earths.

A description of the process is as follows: The ore is crushed to a certain fineness, depending on the character of the gangue. It is then placed in leaching vats, with false bottoms for filtration, the same as other leaching plants. A solution of cyanide of potassium and other chemicals of known percentage is run over the pulp, and left to stand a certain number of hours, depending on the amount of metal to be extracted; it is then drained off and another charge of the same solution is used, but of less strength, which is also drained; the pulp is now washed with clean water, which leaches all the gold and silver out and leaves the tailings ready for discharge, either in cars or sluiced away by water if it is plentiful.

The chemical reaction of cyanide of potassium with gold is as follows, according to Elsner:

$$2\ Au + 4\ K\,Cy + O + H_2O = 2\ KAu\,Cy_2 + 2\ KHO$$

That is, a double cyanide of gold and potassium is formed.

All filtered solutions and washings from the leaching vats being saved and passed through a precipitating " box " of novel construction, which may consist either of glass, iron or wood, and

made in any shape, either oval, round or rectangular—if the latter, it will be about ten feet long, four feet wide and one foot high—and is partitioned off into five lengthwise compartments; under each partition on the inside, or bottom of the "box," grooves may be cut, a quarter to a half inch deep, extending parallel with the partitions, to serve as a reservoir for the amalgam, and give a rolling motion to the solution as it passes along and through the four compartments. The center compartment is used to hold the lead or other suitable anode and electrolyte.

The anode is supported on a movable frame or bracket, so it may be moved either up or down as desired, it being worked by thumb screws at each end.

The electrolyte may consist of saturated solutions of soluble alkaline metals and earths. The sides or partitions of each compartment dip into the mercury, which must cover the "box" evenly on the bottom to the depth of about a half inch.

Amalgamated copper strips or disks are placed in contact with the mercury and extend above it, to allow the gold and silver solution of cyanide to come in contact.

The electrodes are connected with the electric dynamo; the anode of lead being positive and the cathode of mercury being negative. The dynamo is started, and a current of high amperage and low voltage is generated, generally 100 to 125 amperes, and with sufficient pressure to decompose the electrolyte between the anode and cathode.

As the gas is generated at the anode, a commotion is created in the liquid, which brings fresh and saturated solution of electrolyte between the electrodes for electrolysis, and makes it continuous in its action.

The solution of the double cyanide of gold, silver and potassium, which has been drained from the leaching vats, is passed over the mercury in the precipitating "box" when the decomposition of the electrolyte by the electric current is being accomplished, the gold and silver are set free and unite with the mercury, and are also deposited on the plates or disks of copper, forming amalgam, which is collected and made marketable by the well-known and tried methods. The above solution is regenerated with cyanide of potassium by the setting free of the metals in the passage over the "box."

In using this solution again for a fresh charge of pulp, it is reinforced to the desired percentage, or strengthened with cyanide of potassium and other chemicals, and is always in good condition for continuing the operation of dissolving.

The chemical reaction of forming cyanide of potassium in the precipitating "box" is as follows, per Elsner:

$$2\,K + 2\,H_2O = 2\,KOH + H_2$$
$$2\,(Au\,K\,Cy_2) + H_2 = 2\,KCy + 2\,HCy + 2\,Au$$
$$2\,HCy + 2\,KOH = 2\,KCy + 2\,H_2O$$

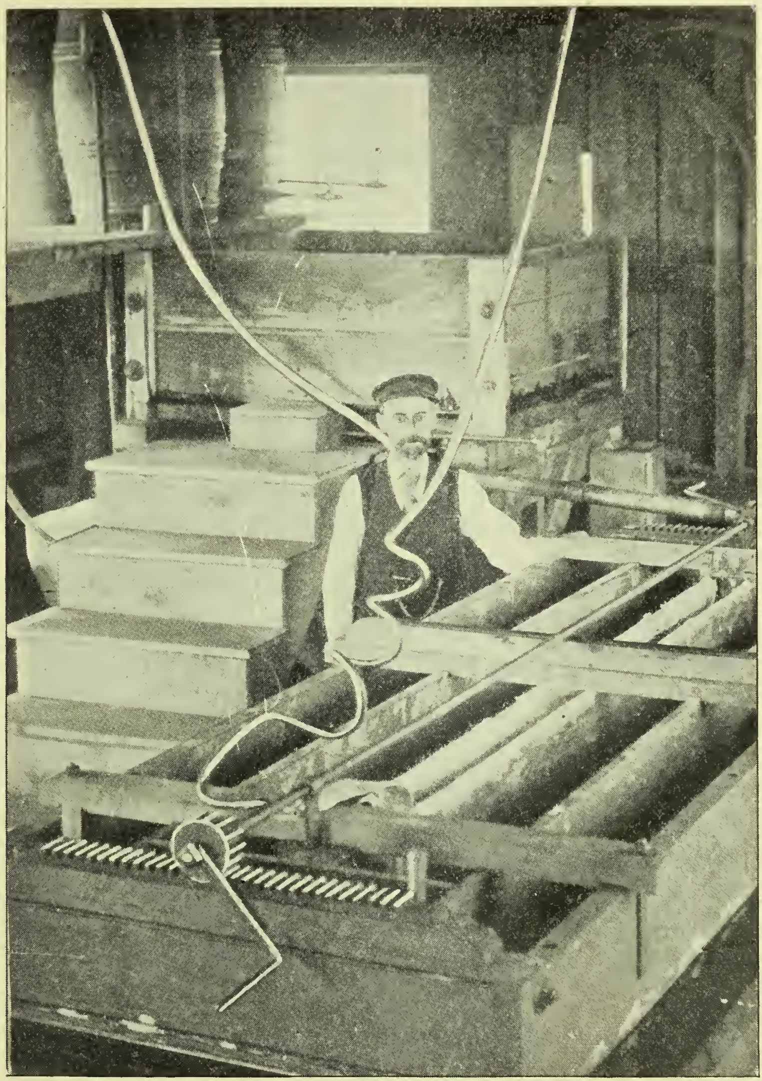
Which is explained thus: The potassium acting on the water of the solution, creates nascent hydrogen and potassium hydrate; the nascent hydrogen sets free the metals (gold and silver), which are precipitated into the mercury and form amalgam, leaving hydrocyanic acid; this latter combines with the potassium hydrate of the former reaction, thus forming cyanide of potassium. There are other reactions, for which I have not at present the chemical formulas.

As the solution passes over the mercury, the center compartment of the "box" is moved slowly longitudinally, which spreads the mercury, the solution is agitated and comes in perfect contact with the mercury, as well as the amalgamated plates or disks of copper, insuring a perfect precipitation.

It is not always necessary to precipitate all of the gold and silver from the solution, for it is used over and over again indefinitely; but when it is required, it can be done perfectly and cheaply in a very short time.

No solution leached from the pulp, containing cyanide of potassium, gold and silver, need be run to waste, which is in itself an enormous saving over the use of zinc shavings when handling large quantities of pulp and solution.

Some of the advantages the electro-chemical process has over other cyanide processes are: Its cleanliness, quickness of action, cheapness, and large saving in cyanide of potassium by regeneration; not wasting the solutions, larger recovery of the gold and silver from the solutions; the cost of recovery less, the loss of gold, silver and cyanide of potassium reduced to a minimum; the use of caustic alkalies in such quantity as may be desired, to



View of Apparatus.

keep the cyanide solution from being destroyed by the acidity of the pulp, and also sometimes to give warmth, as a warm cyanide solution will dissolve gold and silver quicker than a cold one. These caustic alkalies do not interfere or prevent the perfect precipitation of the metals. The bullion recovered in this process is very fine, while the zinc-precipitated bullion is only about 700 fine.

The gold and silver is dissolved and then precipitated in one operation, which we know cannot be done in the "chlorination process;" besides, the cost of plant and treatment is much less in the above described process.

The electro-chemical process, which I have hastily sketched, will, I think, be the future cheap method of recovering fine or flour gold from our mines and waste tailing or ore dumps.

Without going into details of cost of treatment, I will state that with a plant of a capacity of handling 10,000 tons of pulp per month, the cost should not exceed $2 per ton, but that may be cheapened by labor-saving devices. There being no expensive machinery, a plant could be very cheaply erected wherever necessary.

The photograph attached needs not much explanation. The barrels shown are the storage tanks for solutions of different strengths of cyanide of potassium and other chemicals. The square box or vat lower down receives the pulp and solution, and after filtration the solution passes through pipe shown into the precipitating "box," and then into a sump not shown, from which it is pumped back into the barrels. As may be noticed, the solution will run by gravitation to the precipitating "box," there it is relieved of its metals, and then flows into the sump to be pumped back into the barrels, thus causing no losses of the metals by leakage in pumping. The "box" is connected by the electrodes or wires from a dynamo not shown.

SUPPLEMENT.

Read, October 20, 1894.

Sir Humphrey Davy first electro-deposited the metal sodium in the year 1807, and deposited it easily into mercury, form-

ing an amalgam by a crude though effective method. He first made a cup-shaped receptacle of moistened carbonate of soda, placed it upon a platinum plate, the cup was filled with mercury and made the cathode, and the platinum plate the anode; then, with a current of electricity from a powerful battery, the metal sodium was deposited into the mercury, thus forming an amalgam. Also, in the year 1837, in the Philosophical Transactions of the Royal Society, it is stated that Dr. Golding Bird, in 1837, decomposed, by means of a voltaic current, solutions of the chlorides of sodium, potassium and ammonium, depositing their respective metals on a negative pole of mercury, and thus obtained their amalgams.

It has been traced back to the year 1840, that Mr. John Wright dissolved gold and silver in cyanide of potassium solutions successfully. A patent was taken out March 25, 1840, by Messrs. G. R. and H. Elkington, of London, who incorporated in their patent the above discovery of Mr. Wright, for the use of soluble alkaline cyanides in any strength solutions required for dissolving metallic gold, silver, or any other metal; also any compound of these metals in a finely divided condition, such as a chloride precipitate, etc. The use of cyanide of potassium, or any of the soluble alkaline earths, for dissolving metals, has become public property since the expiration of the above patent of Messrs. Elkington.

I call attention specially to the above facts, to show that the ideas of using electricity for the making of alkaline metal amalgams, and the use of cyanide of potassium in particular for dissolving metals, were both well known years ago.

In the year 1837, electro-metallurgy was brought into prominence by the many experiments made upon the deposition of different metals; but it was not until recent years that the ideas then advanced were put into practical shape and successful operation. Modern mechanical devices and the powerful electric dynamo have made possible the rapid strides in electro-metallurgy.

In the electro-chemical process, which I have described in the above paper, the ideas of Sir Humphrey Davy and Mr. John Wright have been utilized to a certain extent in making sodium

and potassium amalgams by the electric current, and the dissolving of metals with the cyanides; but the construction of the precipitating " box " used in the described process, whereby the gold and silver only may be extracted perfectly from an old plating solution of cyanide, or from a cyanide solution leached from gold and silver ores, is new.

It is well known to chemists that the silver of an old cyanide-plating solution cannot be satisfactorily converted into pure chloride by adding an excess of hydrochloric acid, and boiling the mixture; the precipitate so obtained is of different colors, and contains foreign substances; while, with the electro-chemical process, the gold and silver only were precipitated, as was clearly shown by the assay of the resultant bullion, which was 990 fine. The cyanide solution tested, contained large percentages of copper, lead, zinc and iron, with small percentages of manganese, carbonate of lime, etc., which were left in the solution, not being precipitated with the gold and silver. Surely, a more severe test could not have been taken for the demonstration of the advantages of the process.

It may be suggested, since the above metals were in combination, as the double cyanide with potassium and sodium, that the gold and silver are electro-negative to hydrogenium-potassium, or hydrogenium-sodium amalgams, depending on the electrolyte decomposed. Water requires about 1.5 volts to decompose it by an electric current; caustic soda requires over 2 volts, yet if mercury is present to absorb the sodium as it is set free and protect it from the water, we shall obtain sodium amalgam, while the water is decomposed, at the same time forming hydrogenium amalgam. These amalgams thus formed in the precipitating " box " coming into contact with the solution of the double cyanide of gold and silver, aid the setting of them (gold and silver) free, the mercury immediately absorbs them, and forms the amalgam, which is easily collected, retorted, and smelted into bullion. There may be other theories advanced by those more familiar with the subject, but the results obtained are more than flattering.

In examining the recovered gold and silver amalgam after a " clean-up," there were discovered through it hard lumps or nodules, some crystalline in form, having a bright metallic appear-

ance, different from the surrounding mass. I would be pleased to know if any one can give an explanation of the formation of the above forms, as it presents a curious phenomenon.

The above process will be worked by the Electro-Chemical Reduction Company on a large scale in different gold- and silver-bearing countries.

The process is not adapted to all refractory ores; some need a previous treatment, as was the case with ores tested from the Lucky Cuss Mine, at Tombstone, Arizona. The ore contained silver, gold, and about 35 per cent. of manganese. By the simple process of leaching, only 3 per cent. of the bullion was recovered; but by first roasting with 10 per cent. of common salt, and then by the electro-chemical process, over 92 per cent. of the bullion was extracted. Fuel is a great factor to be taken into consideration. At Tombstone, wood costs, delivered, $9.00 per cord, which makes it out of the question to treat their low-grade manganese ores. In other localities, where gold is found in a finely-divided or flour condition, the cost of working this process is the cheapest known, taking into consideration the amount of bullion recovered.

In the chlorination process, if 95 per cent. is recovered from the concentrates, containing say 6 ounces of gold, there is lost 0.3 ounces, or 6 pennyweights, in the tailings. In the electro-chemical process pulp containing but 0.5 ounces gold is treated, and 85 per cent., or more, of the assay value is recovered; and there is lost about 0.075 ounces, or 1.5 pennyweights, of gold in the tailings. The advantage of the latter process is obvious, even if the cost of treatment were the same, which is not the case.

The possibilities of the electro-chemical process are unlimited, as the precipitating "box" may be used to extract gold and silver from the ores direct, or from other solutions than the above-mentioned cyanides.

XVI.

ATMOSPHERIC RESISTANCE.

Notes on the Results of Some Experiments to Determine the Resistance of the Atmosphere to the Free Fall of Spheres.

By Prof. Walter L. Webb, Active Member of the Club.

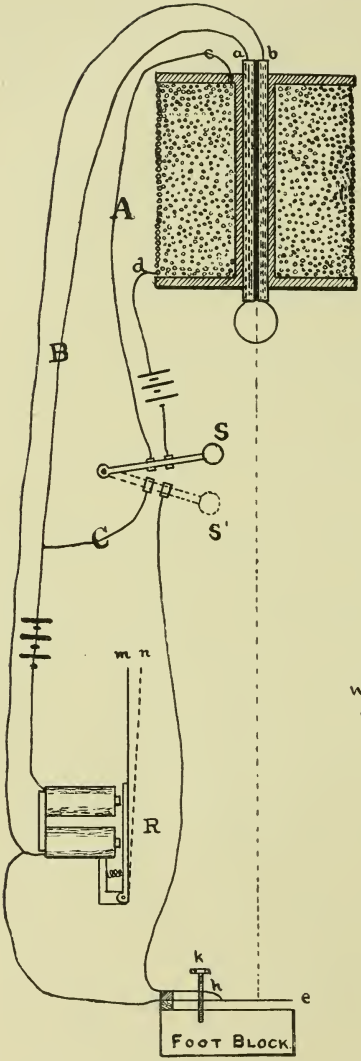
Read, October 6, 1894.

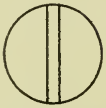
[The following recorded experiments were made while the writer was an instructor at Cornell University. The contemplated long series of experiments were never completed, but the results that were obtained evidenced such a degree of accuracy that it is believed that a publication of the particular methods used and of the conclusions that can be drawn even from the incomplete experiments, will be of value to those interested in the subject and that it may lead others to continue the investigation along similar lines.]

The fundamental idea of the design of the apparatus used was the elimination of all inaccuracies due to friction or inertia. The spheres were to be instantaneously released—the exact instant of release (to the ten-thousandth of a second) determinable—no resistance to falling except atmospheric resistance—height of fall exactly known—the time of reaching bottom likewise known with equal accuracy. In the recording apparatus every inaccuracy due to friction, inertia, or other cause, was either avoided or made compensating so as not to influence the final result. The temperature, pressure, and humidity of the air were carefully determined at the beginning and end of each set of observations. To avoid the uncertain effect of possible currents of air and also to better insure that the observations for temperature, etc., repre-

sented the actual condition of the air passed through, the balls were dropped down an air-tight shaft having an area over 600 times the area of a meridian section of the balls. This proportion was considered large enough to eliminate all appreciable piston action on the part of the ball.

Two balls were used. One was of soft Norwegian iron, carefully ground and polished to exact sphericity, with diameter of .503 of an inch. The manufacture of the other ball cost the writer much patient care and work. It was desired to have a ball that was truly spherical, of same volume as iron ball and yet much less weight, to consist partly of iron so as to be attracted by a magnet, and finally to be perfectly symmetrical about its iron axis so as not to whirl while falling. This was accomplished with all necessary accuracy as follows: A cylinder of soft iron, about $\frac{3}{32}$ inch in diameter and something over $\frac{1}{2}$ inch long, was carefully turned on a watchmaker's lathe. Without taking the piece out of the chuck, a block of white maple wood, a little over $\frac{1}{2}$ inch cube, with a hole drilled in it the size of the cylinder, was forced over the cylinder. Extreme care was taken that the cylinder was not bent or its centering altered during the operation. The tail center returned to its place perfectly immediately afterward. The turning of the wooden ball then began. Toward the last the ball was ground by means of a steel plate with a hole $\frac{1}{2}$ inch diameter through it, the edges of the hole being very perfect. The tail center was removed, the nub at that end carefully ground down, until the sphere was perfect except its attachment to the chuck by a piece not more than $\frac{1}{16}$ inch in diameter. This was sawed off and finished with a file. The result was a ball measuring by micrometer calipers .503 inch in every diameter, and hence of precisely the same volume as the iron ball, weighing less than one-fifth as much as the iron ball, with enough iron to be held by the magnet, and yet so symmetrical that when tested by dropping from a magnet to a piece of putty, it would invariably strike the putty with an orientation exactly parallel to that when hanging to the magnet. As it certainly could not whirl and invariably regain its original orientation immediately before striking, it probably did not whirl at all.





WOODEN BALL
WITH IRON CORE.

The accompanying diagram will show the principle of the apparatus employed. The core *a b* of the supporting magnet was made of concentric layers of thin soft iron (tin-type plate) in order to reduce hysteresis to a minimum. It was then cut in two parts, and the two halves insulated by a sheet of rubber. When the switch *S* is as shown, the core *a b* is magnetized, and the ball, being placed in position, is held there by the magnet. When the switch *S* is turned to the position *S′*, the current through circuit *A* being broken, the ball is free to fall. But while the ball hangs there, the ball itself (or the iron core of the wooden ball) closes circuit *B*, and the recording stylus *R* will be drawn to the position *m*. When the circuit *B* is actually broken by the ball leaving the magnet, the stylus *R* will be forced back by the spring to *n*. When the switch *S* reaches the position *S′* connection is again established through circuit *C*, and the stylus *R* is drawn back to *m*. When the ball reaches the "foot block" (about 8 feet below), the thin horizontal steel plate *e* is depressed slightly, and contact

with the tongue h is broken, the current is again stopped and again the stylus is forced back to n. By means of the set-screw k (which does not touch the plate e), the tongue h can be raised until it touches the plate e just enough to make electrical connection, and the merest touch of the plate e by the falling ball is enough to break the connection.

In the above method the beginning and ending of the interval are *both* recorded by the *breaking* of an electric circuit under *precisely similar* circumstances. By these means are avoided all uncertainties involved in the hysteresis of the recording magnet; the resistance of the circuit is practically the same for both circuits; the friction of the recording stylus is the same for both records. In short, any circumstance affecting the recording of one end of the interval will probably act with equal effect at the other end. Fortunately, however, there is no uncertainty even here, for if for any reason there is any difference, it is easily detected by the difference in the character of the curves drawn by the recording stylus when it flies back. [For a more detailed account of the chronograph, see an article on "Precision in the Use of the Tuning-fork Chronograph" in the *Journal of Franklin Institute*, September, 1892.] As shown in that article (and illustrated further in this), the times of fall are determined with probable errors, for the mean of a set, of less than .0002 second; the vertical fall was determined with all desired accuracy; the weights of the balls used were determined with delicate chemical balances; the density of the atmosphere was observed; and so all the data necessary for a test of any proposed law of resistance was obtained with an accuracy and freedom from inherent error which has never been obtained in similar experiments as far as is known to the writer. Of course the most difficult and essential determination was the exact time interval, but the method used promised well in its design, and the remarkable agreement of all the individual observations of any one set more than realized the expectations.

To test the accuracy of the work, two independent sets of experiments were made with each of the balls for the height of eight feet. Then, to verify any proposed law, the same balls were dropped a height of about four feet.

The precise atmospheric conditions of the air for the "standard weight of a cubic foot of air" are almost immaterial. Those actually used are the same as those used by General Mayevski in some artillery experiments in Russia, viz.: Air half saturated with vapor, temperature 15° Cent., barometer 750 mm. Under these conditions the air weighs .075283 pounds per cubic foot.

A tabulation of the data for six sets of experiments is given as follows:

Set.	Kind of Ball.	Height Dropped. Feet.	Number of Drops.	Mean Time of Fall. Seconds.	Probable Error. Seconds.	Weight of Ball. Pounds.	Thermometer. F. Wet. °	Thermometer. F. Dry. °	Barometer. Scale. "	Barometer. Thermometer. °	Weight of Air. Pounds per Cubic Feet.	Relative Density. (.075283)	C.
1	Iron.	8.0434	4	.70953	.00012	.0184505	59.05	71.05	29.438	70.3	.072695	.965	.000001401
2	Wood.	"	6	.71438	.00027	.0036847	59.55	71.4	29.427	70.0	.072842	.967	.000000857
3	Iron.	"	4	.70956	.00023	.0184505	58.0	68.7	29.465	67.5	.073360	.974	.000001393
4	Wood.	"	3	.71433	.00049	.0036847	61.8	75.75	28.926	71.75	.071386	.948	.000000868
5	Iron.	4.009	5	.50022	.00011	.0184505	64.0	78.0	29.550	80.5	.073357	.974	.000001547
6	Wood.	"	8	.50329	.00024	.0036847	62.2	76.2	29.490	73.0	.073317		.000001337

The volume of both balls (also volume of air displaced) is .00003856 cubic foot. Sets 5 and 6 were made at same time. The fifth line of thermometer and barometer readings were the readings at the beginning—the sixth line the end—of these two sets. The range in absolute weight of air was evidently very small during the two sets. The quantity C is a coefficient (as hereafter explained) representing resistance in pounds.

As a tentative solution, the above data are discussed on the basis of the common assumption that the resistance varies as the square of the velocity. Suppose G and G_1 represent respectively the weights of the ball in air and of an equal volume of air; C is a coefficient of resistance at standard density of the air; *d is

* It has been assumed that the resistance varies directly as the density of the air. It was part of the original plan to investigate this assumption by a series of experiments in which all conditions except density were as nearly identical as possible and in which great variations in the density would be artificially produced in the air-tight-shaft. In the tests made, however, density plays but a small part, being nearly constant throughout, varying only .2 of 1 per cent. in sets 1 and 2, and therefore affording no escape from the conclusions of this paper.

the relative density of the air; g is the acceleration of gravity, here taken as 32.16181 feet per square second, this being the actual determination made at Cornell University by the U. S. Coast Survey; p is the actual (variable) acceleration of the body. The mass of the ball is $\frac{G + dG_1}{g}$, the accelerating force is * $G - dCv^2$; then since force equals mass times acceleration,

$$G - dC\, v^2 = \frac{G + dG_1}{g}\, p \tag{1}$$

Writing $p = \frac{dv}{dt}$ we have

$$dt = \frac{dv}{\frac{Gg}{G + dG_1} - \frac{dCg}{G + dG_1} v^2} = \frac{G + dG}{dCg} \times \frac{dv}{\frac{G}{dC} - v^2}$$

Calling $\frac{G + dG_1}{dCg} = M$ and $\frac{G}{dC} = N$, we have

$$dt = M \frac{dv}{N - v^2} \tag{2}$$

Integrating both sides between t and o and v and o we have

$$t = \frac{-M}{2\sqrt{N}} \log_e \left(\frac{\sqrt{N} - v}{\sqrt{N} + v} \right).$$

Representing the modulus of the common system of logarithms (2.302585 . . . .) by m, we have, after transposition,

$$-\frac{2\,t\sqrt{N}}{m\,M} = \log_{10} \frac{\sqrt{N} - v}{\sqrt{N} + v}. \text{ Call } \frac{-2\,t\sqrt{N}}{m\,M} = a.$$

Then

$$a = \log_{10} \frac{\sqrt{N} - v}{\sqrt{N} + v}. \tag{3}$$

$$v = \frac{d\,s}{d\,t} \qquad d\,t = \frac{d\,s}{v}.$$

* An objection may be urged that the accelerating force varies with the density of the air, on account of the buoyancy varying with the density. The objection is theoretically valid, and with very great variations in the density would be of importance, but the greatest variation in the air density in any of the experiments was computed to have an effect smaller than could be measured on the extremely sensitive chemical balance used to weigh the spheres.

Eq. (2) can therefore be written

$$ds = M\,\frac{v\,dv}{N - v^2}.$$

Integrating as before,

$$s = -\frac{M}{2}\log_e\left(\frac{N - v^2}{N}\right)$$

$$-\frac{2\,s}{m\,M} = \log_{10}\left(\frac{N - v^2}{N}\right).$$

Call,

$$\frac{-2\,s}{m\,M} = b.$$

Then

$$b = \log_{10}\left(\frac{N - v^2}{N}\right). \tag{4}$$

From Eq. (3),

$$10^a = \frac{\sqrt{N} - v}{\sqrt{N} + v} \qquad 10^a\sqrt{N} + v\,10^a = \sqrt{N} - v.$$

Solving for v,

$$v = \frac{1 - 10^a}{1 + 10^a}\sqrt{N}. \tag{5}$$

From Eq. (4),

$$10^b = \frac{N - v^2}{N} \qquad v^2 = N(1 - 10^b).$$

But from Eq. (5),

$$v^2 = N\left(\frac{1 - 10^a}{1 + 10^a}\right)^2$$

Placing these equal, we have, after some reduction,

$$1 + 10^a = 2 \cdot 10^{\frac{a - b}{2}}$$

Dividing by 10^a,

$$10^{-a} + 1 = 2 \cdot 10^{\frac{a - b}{2} - a} = 2 \cdot 10^{\frac{-a + b}{2}}. \tag{6}$$

But

$$-a = \frac{2\,t\sqrt{N}}{m\,M} = \frac{2\,t\sqrt{\dfrac{G}{d\,C}}}{m\,\dfrac{G + d\,G_1}{g\,d\,C}} = \frac{2\,g\,t\sqrt{G\,d\,C}}{m\,(G + d\,G_1)}.$$

$$-\frac{a + b}{2} = \frac{t\sqrt{\dfrac{G}{d\,C}} + s}{m\,\dfrac{G + d\,G_1}{g\,d\,C}} = \frac{g\,t\sqrt{G\,d\,C} + s\,g\,d\,C}{m\,(G + d\,G_1)}.$$

Substituting these values in Eq. (6), we have

$$10^{\frac{2gt\sqrt{GdC}}{m(G+dG_1)}} + 1 = 2 \times 10^{\frac{gt\sqrt{GdC}+sgdC}{m(G+dG_1)}}. \qquad (7)$$

In this equation C is the only unknown quantity. A direct solution, however, is well nigh impossible. The simplest method is by trial. Substituting in Eq. (7) the data of set 1, the equation becomes

$$10^{143.3241\sqrt{C}} + 1 = 2 \times 10^{71.6620\sqrt{C} + 5875.133\,C} \qquad (8)$$

It is found by trial that when $C = .000001401$ the equation is satisfied.

Writing an equation similar to Eq. (8) with the data from set 3, we find by trial that it is satisfied when $C = .000001393$. These two values differ by less than .6 of 1 per cent.

The values of C for sets 2, 4, 5 and 6 were similarly computed, and the results are given in the last column of the table. If the assumption that the resistance varies as the square of the velocity were true, these values should agree very closely. Their disagreement will be discussed later.

Since the measurement of the time interval might be considered the most doubtful element of the data, the value of C for set 2 was recalculated after assuming a change in the time equal to the probable error of the time, *i. e.*, the time was taken as $.71438 + .00027 = .71465$ sec. The resulting value of C is then .000000891. The change in C is insignificant compared with the great discrepancy between the values for the wooden and for the iron ball.*

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* Right here, a very curious coincidence may be noted. The above change in time (.00027 sec.) is 3.8 per cent. of the excess of .71438 sec. over .70724 sec., the time required for a free fall in vacuo. The *change* in the coefficient C is 3.9 per cent. of the original value. The inquiry naturally arose, is it a mere coincidence or is the coefficient directly proportional to the excess of the actual time over the time required for a free fall in vacuo? As a further test, set 6 was taken, the fall being only about one half as much. The probable error is 6 per cent. of the *excess.* Assuming the time as (.50329+.00024) sec. the coefficient which satisfies the equation is .000001422, an excess of 6.3 per cent. over .000001337. A still severer test of this hypothesis was made by assuming that the time had been increased to .50728 sec., *i. e.*, by making the excess of time precisely double. A sufficiently dense medium would cause the time to increase to this figure. The value of C which then satisfies the equation is .000002735, which is 2.05 times .000001337.

Attention is called to the close agreement of the two values for the iron ball (.000001401 and .000001393), and also for those of the wooden ball (.000000857 and .000000868), and also the great difference between the mean values. In searching for the cause of the differences in these coefficients, which should all be practically the same, if the theory were strictly correct, the following facts must be noted:

(1) Both balls were finished by a process of grinding that ensured nearly perfect sphericity. The wooden ball was very carefully and slowly ground down until its diameter agreed with that of the iron ball, to within .001 inch; and both balls, when tested, had all diameters equal to within .001 inch. Therefore, the volumes of air displaced and the shapes of the resisting surfaces were identical for both balls.

(2) The heights dropped through, whether correctly measured or not, were identical in both cases for both balls; and, therefore, whatever slight errors exist in the measurements for heights dropped, will in no way account for the above large discrepancies.

(3) The careful grinding of both balls, to ensure sphericity *polished* both. The skin friction for either is evidently a very small quantity compared with the total resistance; and certainly the *difference* between the skin frictions for polished hard wood and polished iron cannot account for an increase of over 60 per cent. in the coefficient.

(4) The close agreement of each pair of values in the first four sets, although the observations and calculations for each set are entirely independent of each other, show the reliability of the values obtained. The slight differences produced in the coefficient by an assumed change in the time equal to the probable error, also show that the large differences in the coefficients for the wooden and iron balls cannot have been caused by error in the experimental work.

(5) The larger coefficient of resistance occurs with the iron ball. If the reverse were true, it might be inferred that the iron core of the wooden ball, if not symmetrically placed so that the center of mass coincided with the center of volume, caused an oscillation, or rotation, in the ball, which would increase the coefficient

of resistance. But the difference is the other way. It can hardly be imagined that the iron ball is so heterogeneous as to cause such a difference as above noted.

(6) Note that for the shorter fall the coefficients are in both cases increased very materially.

(7) Since the volumes and forms of the balls are precisely the same, and the skin friction is evidently very nearly, if not quite, the same for both, the great difference in the resistances must be due to something connected with the only marked difference between them, viz., their relative masses. The ratio of mass to the resisting pressure of the air being so much larger in the case of the iron ball than in that of the wooden ball, the acceleration of the iron ball is greater at any given velocity than that of the wooden ball at the same velocity. This can be shown as follows: If a ball were employed whose density relatively to air were very large, the ball would fall practically as if in vacuo; *i. e.*, with a constant acceleration very nearly equal to "g." On the other hand, if the ball were but little heavier than air, its acceleration would be always very small, even though it fell far enough to finally attain considerable velocity; and, therefore, its acceleration at any velocity (*e. g.*, v = 10 feet per second) would be less than that of the heavy ball at the same velocity.

From the very nature of the experiments made, it is only possible to test proposed laws and not to deduce the law. But the following is suggested as a law which will fulfill the conditions at least more nearly than the law of the square. Suppose we rewrite Eq. 1 as follows (introducing another resistance term):

$$G - dCv^2 - dDp = \frac{G + dG_1}{g} p \qquad (1')$$

In Eq. (1), dCv^2 is the only resistance term, and with the iron ball C must be comparatively large to satisfy the equation, but p is likewise comparatively large. So that it is evidently possible to find values for C and D that will satisfy Eq. (1′) when the data of sets 1 and 2 are used, there being two equations and two unknown quantities. Since sets 3 and 4 are nearly the same as 1 and 2, the same values of C and D would probably answer very nearly for them. The real test would be to apply the same values of C and D to sets 5 and 6.

In the shorter fall the average velocity was very much smaller, but the acceleration probably nearly constant. Again this additional term would satisfy the results better, for the shorter fall required the larger coefficient. Therefore putting part of it in a term that is nearly constant would allow the coefficient C to remain constant for both (and all) cases. Eq. (1′) can be transposed to

$$G - dC\,v^2 = \left(\frac{G + dG_1 + dDg}{g}\right) p$$

This equation is of precisely the same form as Eq. 1, the only difference being the substitution of $(G + d\,G_1 + d\,Dg)$ for $(G + d\,G_1)$. Making this substitution in Eq. (7) we have

$$10^{\frac{2\,gt\sqrt{G\,d\,C}}{m\,(G + d\,G_1 + d\,Dg)}} + 1 = 2 \times 10^{\frac{gt\sqrt{G\,d\,C} + s\,g\,d\,C}{m\,(G + d\,G_1 + d\,Dg)}} \qquad (7')$$

Substituting the values of t, s, etc., for set 1, we have

$$10^{\frac{6.08988\sqrt{C}}{.0425001 + 71.46336\,D}} + 1 = 2 \times 10^{\frac{3.044941\sqrt{C} + 249.6361\,C}{.0425001 + 71.46336\,D}} \qquad (8')$$

Substituting similarly the data of set 2, we have

$$10^{\frac{2.74295\sqrt{C}}{.0084908 + 71.61148\,D}} + 1 = 2 \times 10^{\frac{1.371475\sqrt{C} + 250.1535\,C}{.0084908 + 71.61148\,D}} \qquad (8')$$

The solution of these equations by approximation (as was done before) is a hopeless task, as it is impossible to guess what combination of values for C and D would satisfy both equations at once. It is equally impossible, by any ordinary means, to eliminate one unknown quantity between the equations and solve for the other. A solution of perhaps sufficient accuracy may be found by employing graphics. For simplicity, the two equations (8′) may be transformed into the simpler algebraic forms

$$\left.\begin{array}{l} 2 \times 10^{\frac{\alpha\,x + \beta\,x^2}{\gamma + \delta\,y}} - 10^{\frac{2\,\alpha\,x}{\gamma + \delta\,y}} - 1 = 0 \\ 2 \times 10^{\frac{\alpha_1\,x + \beta_1\,x^2}{\gamma_1 + \delta\;y}} - 10^{\frac{2\,\alpha_1\,x}{\gamma_1 + \delta_1\,y}} - 1 = 0 \end{array}\right\} \qquad (9')$$

wherein $\alpha\,\beta, \ldots.\ \delta_1$ are given and x and y are the unknown $\sqrt{C}$ and D. These equations are in the form of

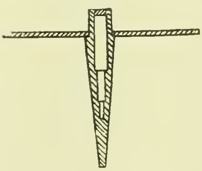
$$2 \times 10^m - 10^n - 1 = 0 \qquad (10')$$

From this equation a curve can be plotted giving the simultaneous values of m and n. But from equations (9′) and (10′) we may write

$$\frac{m}{n} = \tfrac{1}{2} \left(1 + \frac{\beta}{a}\, x\right) \tag{11′}$$

For any assumed value of x, there is a corresponding value of $\frac{m}{n}$. Determine from the plot the corresponding values of m and n which have this ratio and then, either being known, y is determinable. The corresponding values of x and y can then be plotted for equation (9′ (a)). Treating the other equation (9′ (b)) similarly, we would have another curve of values for x and y. The intersection of these two curves would be the simultaneous values of x and y that would satisfy both equations and would therefore be the required values of $1/C$ and D. This graphical method was suggested to the writer by Professor J. E. Oliver, of Cornell University. As may be readily seen, the process is long and tedious, although it is the only practicable method known to the writer. On account of the very limited number of experiments yet made, this process has not been carried through for these equations, for the results in the cases of these isolated experiments would be valueless, and the experiments are yet too few in number to establish the general law as proposed.

A remarkable verification of the figures obtained for spheres is found in the results of some experiments that were made with the same apparatus to determine the resistance encountered by thin flat disks. The disks were about one inch in diameter, and had a slender iron stem which so lowered the center of gravity that they would fall vertically and without "sailing," the disk always remaining horizontal. The stem also ensured that the "foot plate" would be touched before the disk fell so near it that there would be any cushion effect from the air between. Two disks were made with precisely the same area, but slightly varying thickness. The stems were of precisely the same form and size. By boring out the iron stem and using wood instead of brass for the disk, the weight of one was reduced



SECTION OF LIGHT DISK WITH HOLLOW STEM.

to a little over one-fourth that of the other. The slight (and not easily avoidable) difference in the thickness of disks certainly had such a slight effect that for the purpose of this discussion we may consider the volumes of the two disks as identical. By observing all the data and making computations similar to those for the spheres, values were obtained in each case for "C." It is not only a check on the experimental work, but a verification of the deductions just made to note how the value of C, which should be practically the same for all cases of the spheres, and also for all cases of the disks, varies in precisely the same manner, as shown in the table. In both sets, while the volume and form remains constant (or practically so), the weight varies greatly, and also the height fallen through. From the table it may be noted that reducing the height increases C in every case; that reducing the weight (form and volume remaining constant) decreases C in every case.

		Spheres.	Disks.
8-foot fall	Heavy.	.000001397	.000008005
	Light.	.000000863	.000007727
4-foot fall	Heavy.	.000001547	.000009302
	Light.	.000001337	.000008981

Finally, there can be but one conclusion drawn from the results of so many independent experiments made under such diverse circumstances and with so many checks on the experimental accuracy—atmospheric resistance *does not* vary as the square of the velocity.

A few years ago, Mr. Crosby published an article claiming to have demonstrated by experiment that atmospheric resistance varies as the first power of the velocity. The experiments were carried out on a large scale and the resulting figures were certainly remarkable, and therefore it will not do to dismiss the claim with a few words, but it must be said that these experiments in no way verify his claim. An equation was formed similar to Eq. (1) using v in place of v^2. By similar transformation and integration the following equation was evolved:

$$10^{\frac{-t\,d\,g\,C}{m\,(G + d\,G_1)}} = \frac{t\,g\,G}{G + d\,G_1} - \frac{s\,d\,g}{G + d\,G_1}\,C.$$

Using the data of sets 1 and 2, values were obtained for *C*. That for the iron ball was over five times that for the wooden ball. With still greater reason than before, it can be maintained that experimental inaccuracy will not account for this discrepancy.

Various other proposals have been made, especially as the result of artillery experiments—that the resistance varies as the third, fourth or higher powers of the velocity or that it varies as some fractional power, between 2 and 3 or 3 and 4. An attempt was made to investigate these proposals, but it was very soon found to be practically impossible to transform and integrate the fundamental equations so as to eliminate v and p, the unknown variables, and obtain equations involving only the known quantities and the required resistance term.

In conclusion, the writer hopes the foregoing, which he is painfully aware is but a beginning of the real problem, may be an encouragement and perhaps in some respects an aid to some one who will follow it up and obtain results which will have a practical value.

XVII.

NOTES ON UNIT STRESSES FOR RAILROAD BRIDGES OF WROUGHT IRON.

By Prof. Silas G. Comfort, Active Member of the Club.

Read, October 20, 1894.

It is not the purpose of the writer to present anything essentially new, nor to advance any special theories of his own; but rather, to give certain data which he collected during the past summer, showing the present practice of some of the leading railroad companies regarding the specified safe unit stresses, to be used in the proportioning of the members of railroad bridges of wrought iron.

Many of the important railway companies are not represented in the specifications from which the data for this paper have been taken; nevertheless, those used are sufficient to illustrate the variations existing in current practice. A list of these specifications is given below. The dates given are to be understood as the dates of issue only, since, in each case the copy in the possession of the writer was obtained during the past summer in response to a request, addressed to either the Chief Engineer or Bridge Engineer, for a copy of the standard bridge specifications at present used by his company. The abbreviations prefixed to the specifications are used later on for the purpose of simplification in the making of references and in the preparation of tabular matter.

Specifications Consulted.

P. R. R.—Pennsylvania Railroad. Standard Specifications for Wrought Iron Bridges. March 1, 1887.

C. and O.—Chesapeake and Ohio Railway Company. Bridge Specifications. November 1, 1892.

B. and O.—Baltimore and Ohio Railroad Company. Standard Specifications for Iron and Steel Bridges and Viaducts.* 1894.

* The B. and O. specifications state that the ultimate strength, limit of elasticity, elongation, etc., shall be governed by the manufacturers' standard specifications; therefore when speaking of the B. and O. requirements for the quality of iron to be used, the provisions contained in the manufacturers' standard are given.

Un. Pac.—Union Pacific System. Standard Specifications for Materials and Workmanship of Iron and Steel Structures.* 1890.

L. S. and M. S.—Lake Shore and Michigan Southern Railway Company. Specifications for Iron Bridges. 1888.

P. and R.—Philadelphia and Reading Railroad Company. Specifications for Iron and Steel Bridges. January, 1893.

A., T. and S. F.—Atchison, Topeka and Santa Fé Railroad. Specifications for Metallic Bridges. 1894.

N. Y. Cent.—New York Central and Hudson River Railroad Company. Specification of the Materials and Workmanship Required for the Superstructure of Bridge No. ——. 189–.

Mich. Cent.—Michigan Central Railroad Company. Specification for Iron and Steel Bridges. February, 1893.

N. Y., L. E. and W.—New York, Lake Erie and Western Railroad Company. General Specifications for Iron Bridges, 1891.

N. Y., N. H. and H.—New York, New Haven and Hartford Railroad Company. General Specifications for Railroad Bridges of Wrought Iron.

Mo. Pac.—The Missouri Pacific Railway and leased lines. Specifications for Iron and Steel Bridges.

Wabash.—The Wabash Railroad Company. General Specifications for Iron Truss Bridges.† 1891.

Cooper.—"General Specifications for Iron and Steel Railroad Bridges and Viaducts." [New and revised edition, 1890.] By Theodore Cooper.

Bouscaren.—"General Specifications of Railway Bridges and Viaducts of Iron and Steel." [Second edition, revised, 1890.] By G. Bouscaren.

It is very difficult to make any exact comparison between the various unit stress formulas. There are, however, certain conditions which must enter into any such comparison, and it is to these conditions that the writer desires to call attention.

The first to be considered is the requirements for the quality

* "These specifications are not entirely satisfactory, and it is my intention to re-write them at an early date."—Extract from letter of Mr. George H. Pegram, Chief Engineer, dated August 17, 1894.

† "I intend to revise, as some changes should be made."—Extract from letter of Mr. W. S. Lincoln, Chief Engineer, dated August 20, 1894.

of the iron to be used. There are many points under this head in which the various specifications practically agree, and only such points as may be classed as exceptions will be credited to the individual companies. Proceeding, therefore, to the specifications for the quality of wrought iron:

All wrought iron used in the structure shall be tough, ductile, fibrous and uniform in quality for each class, free from injurious seams, buckles, blisters, cinder pockets or imperfect edges, and must be capable of being worked at a proper heat without injury. No specific process or provision of manufacture will be demanded, provided the material fulfils the requirements of these specifications.

Exceptions are:

"All iron to be used in the tensile members of open trusses, laterals, pins and bolts must be double rolled after and directly from the muck bar (no scrap will be allowed)."—*P. R. R.*

"Iron for tension must be made directly from the muck bar, or shall be rolled from piles composed of piling pieces, each the full length of the pile. The use of old rails will not be allowed."—*L. S. and M. S.*

"In rolling, all piles must have both top and bottom cover-plates."—*A., T. and S. F.*

"Wrought iron shall be double rolled directly from the muck bar. No scrap iron will be allowed. . . . . All plates up to 36 inches in width must be rolled in the Universal Mill."—*N. Y. Cent.*

"For all tension members the muck bars shall be rolled into flats and again cut, piled and rolled into finished bars. No scrap will be allowed."—*N. Y., L. E. and W.*

It shall have an elastic limit of not less than 26,000 pounds per square inch.

Exceptions are:

25,000 pounds for iron to be used in the tensile members of open trusses, laterals, pins and bolts; and 23,000 pounds for other classes of iron.—*P. R. R.*

25,000 pounds for plates over twenty-four inches wide.—*C. and O.*

25,000 pounds for all wrought iron.—*L. S. and M. S.*

25,000 pounds for webs of channels and "I" beams and for plates over eighteen inches wide.—*A., T. and S. F.*

25,000 pounds for tests made on full-size bars.—*N. Y. Cent.*

For bars and shaped iron the elastic limit must not be less than one-half the required ultimate strength as given by formula.—*N. Y., N. H. and H.*

Iron to be used in the tensile members of open trusses, laterals, bolts and pins, plate iron not over eight inches wide and shaped iron, must have an elastic limit of not less than one-half the required ultimate strength as given by formula.—*B. and O.* and *Wabash.*

25,000 for full-size tension members.—*Bouscaren.*

The tensile strength, limit of elasticity and ductility shall be determined from standard test pieces cut from the full-size bar. The area of cross-section of these test pieces shall not be less than one-half square inch for a length of ten inches. The elongation shall be measured on an original length of eight inches.

Exceptions are:

"Test pieces shall be one and one-half inches in width, and from one-quarter to three-quarter inches in thickness, planed down on both edges equally, so as to reduce the width to one inch for a length of eight inches. Whenever practicable, the two flat sides of the piece to be left as they come from the rolls. In all other cases, *both* sides of the piece are to be planed off."—*P. R. R.*

"Test pieces shall be of a minimum width, or diameter, of one inch, a minimum total length of fifteen inches (elongation taken in distance of twelve diameters)."—*A., T. and S. F.*

"Test pieces not less than one-quarter inch in thickness, cut from the full-size bar, and planed or turned parallel; if the cross-section is reduced, the tangent between shoulders shall be at least twelve times its shortest dimension, and the area of minimum cross-section in either case shall not be less than one-quarter of a square inch and not more than one square inch. Whenever practicable, two opposite sides of the piece are to be left as they come from the rolls; but the finish of opposite sides must be the same in this respect. A full-size bar, when not exceeding the above limitations, may be used as its own test piece. In determining the ductility, the elongation shall be measured after breaking on an original length the nearest multiple of a quarter inch to ten times the shortest dimension of the test piece (in which length must occur the curve of reduction on both sides of the point of fracture), but in no case on a shorter length than five inches."—*B. and O.; N. Y., N. H. and H.*, and *Wabash.*

"Elongation taken in a distance of twelve diameters."—*Bouscaren.*

The requirements for ultimate strength and percentage of elongation, as shown by test, are given in Table I. This table is, in one sense, unnecessarily long; but it is only by using many divisions under the head of plates that the exact requirements of each specification can be fully shown. Numerous foot-notes have been found necessary owing to the use of formulas and special provisions governing the determination of either the ultimate strength or elongation. Furthermore, it must be borne in mind that the distance in which the elongation is to be taken is not in all cases equal to eight inches, and for these variations reference may be made to the statement of requirements for test pieces already given.

The ultimate strength and elongation required to be shown

by tests on full size tension members vary greatly, and on this account the full requirements of each specification are given.

"When tested to breaking . . . . the bars and rods must part through the body of the bar and not through the head or pin hole."—*P. R. R.*

"When full size tension members are tested to prove the strength of their connections, a reduction in their ultimate strength of (500 $\times$ width of bar) pounds per square inch will be allowed."—*C. and O.*

"To determine the strength of the eyes, full size bars or rods with eyes may be tested to destruction . . . . and any lots of bars from which full size samples are taken shall be accepted. . . . .

1. If not more than one-third of the bars break in the eye ; or

2. If more than one-third do break in the eye and the average of the tests of those which so break show a tensile strength in pounds per square inch, given by the formula

$52000 - \frac{7000 \times \text{area of original bar}}{\text{circumference of original bar}} - 500 \times$ width of bar (all in inches), and not more than one-half of those which break in the eye fail at more than 5 per cent. below the strength given by the formula."—*B. and O.*

"Full size pieces of flat, round or square iron, not over two (2) square inches in sectional area, shall have an ultimate strength of at least 50,000 pounds per square inch and stretch at least 10 per cent. in their length. Bars of larger sectional area than two (2) square inches will be allowed a reduction of 1,000 pounds per square inch of section, down to minimum of 46,000 pounds per square inch."—*L. S. and M. S.*

"Full size finished eye-bars or rods with eyes, when tested to destruction, will be allowed a reduction of (500 $\times$ width of bar) pounds per square inch, with a minimum limit of 46,000 pounds, and an elongation of not less than 15 per cent. in a length of 10 feet.—*P. and R.*

"Tests made on full size bars shall show not less than 46,000 pounds per square inch of ultimate tensile strength and an elastic limit of not less than 25,000 pounds per square inch."—*N. Y. Cent.*

"Full-sized pieces of bar iron shall show the qualities specified for the small specimens cut from them, except that bars having a sectional area of more than 4½ square inches will be allowed a reduction in ultimate strength of 1,000 pounds per square inch for each additional square inch of section down to a minimum of 46,000 pounds per square inch."—*Mich. C.*

"Full-sized pieces of flat, round or square iron, not over 4½ inches in sectional area, shall have an ultimate strength of 50,000 pounds per square inch, and stretch 12½ per cent. their whole length. Bars of a larger sectional area than 4½ square inches, when tested in the usual way, will be allowed a reduction of 1,000 pounds per square inch, for each additional square inch of section, down to a minimum of 46,000 pounds per square inch."—*N. Y., L. E. and W.*

"The ultimate strength of any finished tension member shall not be less than 45,000 pounds per square inch, and the limit of elasticity shall not be less than 25,000 pounds per square inch on exposed area."—*N. Y., N. H. and H.*

TABLE I.

Ultimate Strength of Wrought Iron in Pounds per Square Inch and Per Cent. of Elongation, as Shown by Test Pieces.

Class of Wrought Iron.	P. R. R.	C. and O.	B. and O.	Un. Pac.	L. S. and M. S.	P. and R.	A., T. and S. F.	N. Y. Cent.	Mich. C.	N. Y., L. E. and W.	N. Y., N. H. and H.	Mo. Pac.	Wabash.	Cooper.	Bouscaren.
Ultimate Strength.															
Eye-bars, rods, etc.	50,000	*a*	*b*	*c*	*d*	*b*	*a*	52,000	50,000	*c*	*e*	*f*	*b*	*f*	*g*
Shapes	46,000	48,000	*h*	48,000 to 50,000	48,000	*h*	50,000*	50,000	48,000	48,000	*e*	48,000	*h*	48,000	50,000
Plates:															
Less than 8 inches wide			*b*			*b*					*e*		*b*		
" 18 "							50,000								
" 24 "	46,000	48,000			48,000			50,000		48,000		48,000		48,000	50,000
" 36 "									48,000						
8 inches to 24 inches wide			48,000	47,000		48,000					48,000		48,000		
18 " 36 "							48,000								
24 " 36 "						47,000									
36 " 54 "							47,000								
Over 24 inches wide	46,000	46,000	46,000	46,000	46,000			48,000		46,000	46,000	46,000	46,000	46,000	48,000
" 36 "						46,000			46,000						
" 54 "							46,000								
Per Cent. of Elongation.															
Eye-bars, rods, etc.	20	18	20	20	18	20	18	20	18	20	*k*	18 to 15	20	18 to 15	20 to 16
Shapes	*i*	12	*k*	15	12	15	15†	15	15	15	*k*	15	*k*	15	15
Plates:															
Less than 8 inches wide			20	15		20					*k*		20		
" 12 "									15						
" 18 "							13								
" 24 "	*i*	12			12			15		15		12		15	15
8 inches to 24 inches wide			12	12		15					12				
12 " 72 "									*l*						
18 " 36 "							10								
24 " 36 "		10	10	10		12					10		10		
36 " 48 "		8	8	8							8		8		
Over 24 inches wide	5				10			12		8		10		10	10
" 36 "						10	8								
" 48 "		5	5	5							5		5		
" 72 "									5						

a. $52{,}000 - \dfrac{5000 \times \text{area of original bar.}}{\text{Circumference of original bar.}}$

b. In *a*, for 5,000 *read* 7,000.

c. $4\frac{1}{2}$ square inches in sectional area and less, 52,000 pounds; for larger cross-section than $4\frac{1}{2}$ square inches will be allowed a reduction of 500 pounds per square inch of section down to a minimum of 50,000 pounds.

d. In *c*, for 52,000 *read* 50,000; and for 50,000 *read* 48,000.

e. 50,000 — 1,750 *d*, in which "d" is the diameter of a circle whose area is equal to the area of the finished member in question.

g. In *c*, for $4\frac{1}{2}$ *read* 4; and for 50,000 *read* 48,000.

h. In *a*, for 52,000 *read* 50,000; and for 5,000 *read* 7,000.

i. All iron to be used in tension or subjected to transverse stress (except web plates), 15 per cent.; and for web plates less than 24 inches wide, 10 per cent.

k. 15 per cent. for bars five-eighths of an inch and less in thickness, and 12 per cent. for bars of greater thickness.

l. $15 - \dfrac{\text{Width} - 12.}{6.}$

* Webs of channels and "I" beams, 47,000 pounds.

To *N. Y., L. E. and W.* requirements add: "and 10 per cent. elongation in the whole length of the body of the bars."—*Mo. Pac.* and *Cooper.*

"To determine the strength of the eyes, full sign eye-bars, or rods with eyes may be tested to destruction . . . . any lot of bars from which full size samples are tested will be accepted: Provided—*First,* that none of the bars tested break in the eye or neck; or *second,* that none of the bars tested show a tensile strength in pounds per square inch of original bar of less than 95 per cent. of that required by the formula for tests on small test-pieces."— *Wabash.*

To *N. Y., N. H and H.* requirements add: "With elongation not less than 10 per cent. in ten feet measured on any part of the bar."—*Bouscaren.*

The following are the requirements of bending tests:

(1) All iron for tension members must bend cold 180 degrees without sign of fracture to a curve whose inner diameter is twice the thickness of the bar.

Exceptions are:

"All tension wrought iron, if cut into testing strips one and one-half inches in width, must be capable of resisting, without signs of fracture, bending cold by blows of a hammer, until the ends of the strips form a right-angle with each other, the inner diameter of the curve of bending being not more than twice the thickness of the piece tested. The hammering must be only on the extremities of the specimens, and never where the flexion is taking place. The bending must stop when the first crack appears."—*P. R. R.*

"Must bend cold for about 90 degrees, ... ; at least one sample in three must bend 120 degrees to this curve without cracking."—*Un. Pac.* and *P. and R.*

"Inner diameter one and one-half times the thickness of bar."—*A., T. and S. F.*

"90 degrees; and at least one sample out of three must bend cold 180 degrees on a curve of same diameter without showing fracture signs."—*N. Y. Cent.* and *Cooper.*

"Inner diameter not more than four times the thickness of the test piece." *Mich. C.*

"90 degrees."—*Mo. Pac.*

"For test specimens, diameter equal to the thickness of the specimen; for full size bars, 90 degrees."— *Bouscaren.*

(2) Specimens of full thickness cut from plate iron, or from the flanges or webs on shaped iron, must stand bending cold through 90 degrees to a curve the inner diameter of which is three times the thickness of the specimen, without sign of fracture.

Exceptions are:

No requirements for bending tests except for tension iron.—*P. R. R.*

"180 degrees."—*C. and O.*

A., T. and S. F.—The requirements of this specification are given in the following Table:

Material.		Angle to which specimen must bend without breaking.	Diameter of bend in terms of thickness of specimen.
Channels and I Beams	Flange	140°	$1\frac{1}{2}$
	Web	140°	2
Angles		140°	$1\frac{1}{2}$
Plates	Under 18″ wide	140°	2
	18″ to 36″ "	140°	3
	36″ to 54″ "	90°	
	over 54″ "	90°	

" Inner diameter not more than four times the thickness of bar."—*Mich. C.*

" Plates wider than 24 inches . . . . curve whose diameter is not more than six times the thickness of plate."—*Cooper.*

" For bars, angles, shapes and plates 24 inches wide and less, the diameter shall be equal to four times the thickness, and for plates more than 24 inches wide, to eight times the thickness."—*Bouscaren.*

In addition to the above, several of the specifications require that " all wrought iron when nicked and bent must show a fracture nearly all fibrous ;" also " all plates, angles, etc., which are to be bent hot in the manufacture must, in addition to the other requirements, be capable of bending sharply to a right angle at a working heat without sign of fracture."

Having before us the requirements for the quality of the iron to be used, we are in a position to examine the unit stresses to be employed in the design of the structure. It is evident that the lack of uniformity in the specified maximum train loads has no actual bearing on the question of the unit stresses. A light train load gives a light bridge, while a heavier train load calls for a heavier bridge. There is, however, one point in regard to the moving or train load that does play an important part in the unit stress to be used, and that is, the manner in which the allowance is made for the effect of impact and vibration. This allowance is made in one of two ways : first, by adding a certain amount to the maximum stress due to the train load, and thus reducing it to an equivalent dead load ; or second, to make this allowance wholly in the unit stresses used. Those specifications containing methods of making this allowance according to the first method will be first considered.

C. and O.—In proportioning the members of the structures the effects of impact and vibrations shall be considered and added to the maximum stresses resulting from the engine and train loads. The effect of impact is to be determined by the following formula:

$$I = S\left(0.7 \times \frac{5}{L}\right).*$$

Where $I =$ effect of impact.

$S =$ calculated maximum live load stress.

$L =$ length of loaded distance in feet, which produces the maximum stress in member.

For plate girders, $L =$ span center to center of bearing.

For floor-beams, $L =$ length of two panels.

For truss-bridges, $L =$ number of panel points loaded $\times$ length of panel.

Mich. C.—The stresses caused by the specified live loads shall be multiplied by $\left(\frac{4}{3} - \frac{L}{300}\right)$ if the loaded length L is less than 100 feet. This does not apply, however, to stresses due to the centrifugal force of the train on a curved track, or to the longitudinal forces caused by setting the breaks when the train is moving.

N. Y., N. H. and H.—Impact from the variable load will be provided for as follows:

Riveted connections and suspenders for floor-beams and track stringers	100	per cent.
Stringers and floor-beams	50	"
Spans, 16 feet to 30 feet	40	"
" 30 " " 50 "	40 to 25	"
" above 50 feet, 25 per cent. minus 1 per cent. for every additional 5 feet of span; 175 feet span = 0 per cent.		
All counter ties and middle panel ties	25	"

Bouscaren.—To provide for the effect of impact and vibration additions to the stresses produced by the above specified live load shall be made as follows:

Riveted connections of stringers and floor-beams, and hangers 2 feet long or less, 100 per cent.

Hangers and suspenders over 2 feet long, 50 $\left(1 + \frac{2}{l}\right)$ per cent., where $l =$ length of hanger or suspender.

Floor-beams, stringers and other plate girders, 50 $\left(1 - \frac{d}{250}\right)$ per cent., where $d =$ one-half length of girder.

Web members of trusses and trestle posts, 50 $\left(1 - \frac{d}{250}\right)$ per cent., where $d =$ distance of member from center of truss.

Chords of trusses, 50 $\left(1 - \frac{d}{250}\right)$ per cent., where $d =$ one-half length of span.

No additions shall be made where d in the above formula exceeds 250.

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* This formula was originally deduced by Mr. C. C. Schneider, Chief Engineer of the Pencoyd Iron Works. The "Pencoyd Specifications for Steel Railroad Bridges," issued in 1894, contains a revised impact formula as follows:

$$I = S\left(0.10 + \frac{220}{L + 240}\right).$$

The specified unit stresses for tension are given in the following Table:

	C. AND O.	MICH. C.		N.Y.,N.H. & H.	BOUSCAREN.
Material.		Live Load.	Dead Load.		
Bars	15,000	8,500	15,000	10,000	12,000
Shapes and plates . .	14,000	7,500	13,000	9,000	10,000

The unit stresses for compression are in each instance modifications of the well-known formula:

$$P = \frac{a}{1 + \frac{l^2}{b\,r^2}}. \qquad (1)$$

in which

P = allowable unit stress.

a = permissible stress on short struts.

b = a constant.

l = length in inches of member between supports.

r = least radius of gyration.

C. and O.—$a = 14{,}000$; $b = 15{,}000$. No compression member, however, shall have a length exceeding 100 times its least radius of gyration, except lateral struts, which may have a length not exceeding 120 times the least radius of gyration.

Mich. C.—For struts if $\frac{l}{r}$ is less than 40, use 7,000 pounds for live load and 12,000 pounds for dead load, otherwise use above formula, in which case $a = 8{,}000$ pounds for live load and 14,000 pounds for dead load; $b = 15{,}000$ for both dead and live loads.

N. Y., N. H. and H.—Compression, length less than 8 times least diameter, 8,000 pounds. When length exceeds this limit, use above formula, in which $a = 8{,}000$, and for—

Two pin bearings . . . . $b = 18{,}000$
One pin bearing and one square bearing . . . . $b = 24{,}000$
Two square bearings . . . . $b = 36{,}000$

No member in compression shall have a width less than one-thirtieth of its unsupported length.

Bouscaren.—In compression for lengths less than 50 times the least radius of gyration 9,000; otherwise use formula, in which case $a = 9{,}000$, and b has the same values as given in *N. Y., N. H. and H.*

The specifications giving no allowance for the effect of impact and vibrations are to be considered.

The unit stresses for tension may be divided into two classes: *First*, those giving a fixed value in pounds per square inch to

the working stress; and, *second*, those giving a value depending upon the ratio of the minimum to the maximum stress in the member.

Those coming under the first class are:

L. S. and M. S.:

Chords and main ties (eye-bars)	9,000
" " " " (plates and shapes)	8,000
Laterals	13,500

Mo. Pac.:

	For Live Loads.	For Dead Loads.
On bottom chords and main diagonals	8,000	16,000

On counters and long verticals:

If forged eye-bars	8,000
If made up of plates or shapes, in tension, net section	7,500
On laterals	15,000

Wabash:

Lower chord and main tie-rods less than 4 square inches in area	10,000
Over 4 square inches in area	9,000
Counter rods	8,000
Long verticals	6,000
Laterals	12,000

Cooper:

	For live loads.	For dead loads.
Bottom chords, main diagonals, counters and long verticals (forged eye-bars)	8,000	16,000
Bottom chords and flanges, main diagonals, counters and long verticals (plates or shapes), net section	7,500	15,000
Lateral bracing	15,000	

Those coming under the second class are:

*P. R. R., B. and O** and *N. Y., L. E. and W.:*

For double rolled iron (links or rods) . . . $7{,}500\left(1+\dfrac{\text{minimum stress}}{\text{maximum stress}}\right)$.

For plates or shapes . . . . $7{,}000\left(\qquad " \qquad\right)$.

P. and R.:

Counter web members and long verticals (eye-bars)	8,000
Lower chord (eye-bars)	10,000

Main web members (eye-bars) . . . . $8{,}000\left(1+\dfrac{\text{min. stress}}{\text{max. stress}}\right)$.

* Bracing:

Wind only	15,000
Centrifugal force or sliding friction	10,000

Lateral and transverse bracing 15,000
Angle iron lateral ties (net section) 12,000

A., T. and S. F.:

For chords and main diagonals—eye-bars . . . . $9{,}000 \times L$.
For chords and main diagonals—plates and shapes . . . . $7{,}500 \times L$.
For counters 8,000
For end suspenders 6,000
For lateral bracing 15,000

The factor L in the first two items being:

$$L = 1 + \tfrac{1}{2}\,\frac{\text{minimum stress}}{\text{maximum stress}}.$$

The compression unit stresses may be divided into two general classes: *First*, those obtained by the use of a right line formula; and, *second*, those obtained by the use of modifications of Rankin's formula.

Those coming under the first class are:

B. and O.:

Chords, posts and main braces . . . . $7{,}000\left(1 + \frac{\text{min.}}{\text{max.}}\right) - 35\,\frac{l}{r}$.

Bracing:

Wind only . . . . $10{,}500 - 52\,\frac{l}{r}$.

Centrifugal force or sliding friction . . . . $7{,}000 - 35\,\frac{l}{r}$.

Mo. Pac. and *Cooper:*

On all posts { for live load stresses . . . . $7{,}000 - 40\frac{l}{r}$.
" dead " " . . . . $14{,}000 - 80\frac{l}{r}$.

On lateral struts, for assumed initial stress . . . . . $9{,}000 - 50\,\frac{l}{r}$.

No compression member, however, shall have a length exceeding 45 times its least width.

Mo. Pac.:

On chord sections { for live load stresses . . . . . . $7{,}500 - 30\frac{l}{r}$.
" dead " " . . . . . . $15{,}000 - 60\frac{l}{r}$.

Cooper:

On chord sections { for live load stresses . . . . . . $8{,}000 - 30\frac{l}{r}$.
" dead " " . . . . . . $16{,}000 - 60\frac{l}{r}$.

On all posts, for wind stresses . . . . $10{,}500 - 60\,\frac{l}{r}$.

Those coming under the second class use formula (1) in calcu-

lating the compression unit stress. The values of a and b are as follows:

P. R. R., L. S. and M. S., N. Y., L. E. and W., and *Wabash:*

$$b \begin{cases} 36{,}000 \text{ for members with two fixed ends.} \\ 24{,}000 \text{ for members with one fixed end and one pin end.} \\ 18{,}000 \text{ for members with two pin ends.} \end{cases}$$

P. R. R. and *N. Y., L. E., and W.:*

$$a = 6{,}500 \left(1 + \frac{\text{min. stress in piece}}{\text{max. stress in piece}} \right)$$

N. Y., L. E. and W.:

"The lateral struts shall be proportioned by the above formulæ, to resist the resultant due to an assumed initial stress of 10,000 pounds per square inch upon all rods attaching to them, produced by adjusting the bridge.

L. S. and M. S.:

$a = 7{,}500.$

Wabash:

$a = 8{,}000.$

"Lateral struts proportioned for 50 per cent. more than the foregoing formula."

"No compression member shall have a length exceeding 45 times its least width."

P. and R.:

Laticed columns:

$$b \begin{cases} 40{,}000 \text{ for flat ends.} \\ 20{,}000 \text{ for pin ends.} \end{cases}$$

$$a = 6{,}500 \left[1 + \frac{\text{min. stress}}{\text{max. stress}} \right] \text{ with a maximum limit of } 8{,}000.$$

Angle iron struts:

Flat ends.	Pin ends.
$P = 9{,}000 - 30 \frac{l}{r}.$	$P = 9{,}000 - 34 \frac{l}{r}.$

"For lateral and transverse struts one and three-tenths times the above values shall be used."

A. T. and S. F.:

$$b \begin{cases} 40{,}000 \text{ for members with two fixed ends.} \\ 30{,}000 \text{ for members with one fixed and one pin end.} \\ 20{,}000 \text{ for members with two pin ends.} \end{cases}$$

$$a \begin{cases} \text{For main truss members, } 7{,}500. \\ \text{For lateral struts, } 10{,}000. \end{cases}$$

"No compression member shall have an unsupported length exceeding forty times its least width."

"The unsupported width of any plate subject to compression shall not exceed thirty-two times its thickness.

In the above list of unit stresses, those of the Union Pacific and New York Central railroads are omitted. This omission is not due to an oversight, but is owing to the failure of the writer to obtain copies of the unit stresses used by these companies.

It may seem somewhat peculiar that Mr. F. H. Lewis' specifications have not been mentioned; but, as Mr. Lewis recently presented his specifications in a paper read before the Club, and afterwards published in the PROCEEDINGS, it was deemed best to omit them from this paper.

In conclusion, as stated at the outset, the unit stresses given in this paper are not exhaustive, but merely indicate the variations to be found in current practice. Also the data presented emphasizes the fact that to state the factor of safety required, furnishes but little information unless the methods for determining ultimate strength and the unit stresses used in obtaining this factor of safety are known.

DISCUSSION.

MR. WILLIAM R. WEBSTER.—Some specifications require bending tests to be made on pieces of steel plates or angles having sheared edges, and punched holes near sheared edges to be enlarged by drifting. These requirements are unreasonable, and I have some samples to show how the conditions under which these tests are made may affect the results.

Here are three pieces marked 1, 2 and 3 from a $\frac{5}{8}$-inch steel plate (which gave 53,180 pounds ultimate strength—46 per cent. elongation in 2 inches and 64.6 per cent. reduction of area)—they were cut side by side from the plate. This material will bend all right, as shown by sample 3, there being no cracks on either sheared edge. But sample 1 is no good—it broke in two pieces; while in No. 2 one edge is good and the other poor. All these bends were made over a pin in same manner by slowly applied pressure.

If you will examine these pieces carefully you will find a depression on the rolled surface extending back about one-eighth of an inch from the sheared edge (the mark is same as the mark of die in punching, only deeper), the metal here was in contact with the shear knife *a*, Fig. 1, and has been compressed and hardened, and will not stand the bending test when on the outside of curve—that is, after being compressed it will not stretch. The rolled surface on other side of plate at corresponding

sheared edges is rounded and will stand much better when on the outside of curve. It is not the fine wire edge that causes the trouble, as you can remove it, and yet the plates will not stand bending.

Sample 2 was sheared in the usual way, as shown in Figs. 1 and 2; that is, after shearing one edge the plate was inserted a

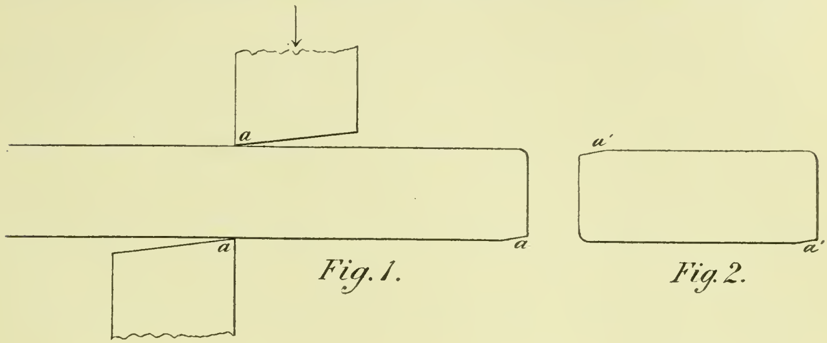

Fig. 1. *Fig. 2.*

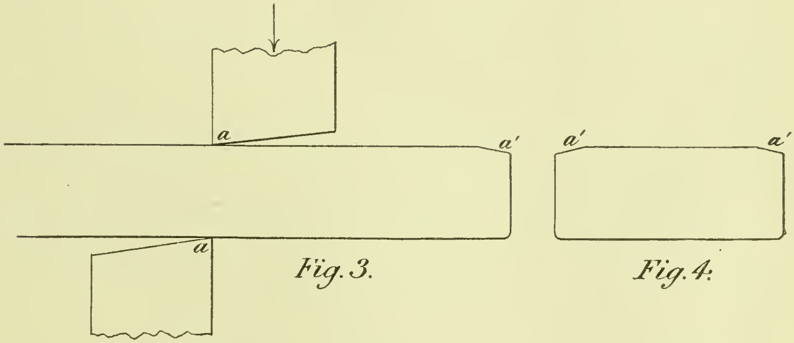

Fig. 3. *Fig. 4.*

little further and a second cut taken, giving one compressed edge, a', and one rounded edge on each side of the plate, therefore you cannot get a good bend whichever side of the plate you have up.

In the other samples the plate was turned over after making the first cut and both of the compressed edges brought on same

side of the plate. See sketches 3 and 4. (This can also be done by turning the plate around, but it is hard to hold in shearing.) In sample 3 both of the compressed edges were on the inside of curve, and the bend is good, while in sample 1 they were both on the outside, and it is no good.

This, no doubt, is old to many of the members, but may be of interest to some of the younger members.

The samples of drifting tests had two three-quarter-inch holes punched in them, and one hole in each case has been enlarged to one and a half times its diameter, while in attempting to enlarge the other hole the plate in each case has broken at the edge. The poor results or failures were caused by using a drift with very slight taper—the metal would not stretch at sheared edge where it had been compressed and hardened. In the other cases a drift of much greater taper was used; it thickened the metal up around the hole, then a drift of less taper was used and the holes enlarged.

This only goes to show the great importance of reducing all our testing to standard methods. In tension tests the rate of pulling speed and poise speed varies at different works and affects the results. It is of the greatest importance to know all of the conditions under which the tests are made. I feel confident that Mr. Vauclain could give us some very valuable information on these points.

Mr. Robert A. Cummings called attention to the fact that the matter of this paper furnished a good illustration of the necessity for co-operation among engineers, in order to arrive at a knowledge of existing differences in theory and practice, and to establish uniformity in these particulars, and that this was one of the purposes for which the International Institute of Engineers and Architects was proposed to be formed.

In answer to a question from Mr. W. C. Furber as to how closely the elastic limit could be determined, and as to what reliance could be placed upon such determinations as a true limit, Prof. Comfort stated that there is one place at least where the work is done with what would seem to be sufficient care, and that is at the Watertown Arsenal, Watertown, Mass., where the tests are made for the Ordnance Department of the Government, and

furthermore, that the values for elastic limits published in the Reports on Tests of Metals issued annually by the Ordnance Department are probably reliable.

Mr. C. H. Davis considered that the elastic limit was a very delusive quantity ordinarily, and that in mills doing much testing its determination was largely a matter of guesswork.

Mr. William R. Webster said that this limit was generally taken by a drop of the beam in the testing machine, which is not an accurate method.

Mr. F. Schumann called attention to the lack of uniformity shown by the paper to exist in the proportions of test-pieces, and mentioned a case that had come under his notice where the elongation of a steel specimen was 25 per cent. at ½-inch thickness, and when the thickness was planed down to ⅛ inch it fell to 16 per cent.

Commenting upon this, Mr. A. Falkenau called attention to some tests now being made by the Edge Moor Iron Company, in which they find that by simply planing the edges of the test-pieces the elastic limit is very considerably altered. This might possibly account for the variations pointed out by Mr. Schumann.

In answer to a question by Mr. Furber as to what variation would be considered allowable in tests made by different parties, Mr. Webster stated, in a series of tests that had been made by six different firms, on specimens cut from the same plate of steel, there was as much variation as 6,000 pounds in the elastic limit. He considered that the autographic device gives more reliable and uniform results than can be obtained with an ordinary testing machine.

THOMAS MUTTER CLEEMANN.

Thomas Mutter Cleemann, son of Gustavus B. C. and Claramond Cleemann, was born in Philadelphia, July 31, 1843. On his father's side he was descended from German ancestry, and on his mother's, from the early English and Scotch settlers of Virginia.

Receiveing his early education at private schools, he was graduated from the University of Pennsylvania, in 1862, with the degree of B.A., and subsequently was graduated from the Rensselaer Polytechnic Institute at Troy, N. Y., in 1865, with the degree of C.E.

His ability and high standing in his class brought him an offer of a college professorship, which, however, he declined, entering the service of the Pennsylvania Railroad Company in July, 1865, as Assistant Engineer under Chief Engineer W. Hazel Wilson.

In 1866 he became Assistant Engineer on the Allegheny Railroad, returning to the service of the Pennsylvania Railroad in 1867, and remaining there until 1872.

In 1872 he was sent by his intimate friend, the late W. W. Evans (Mem. Am. Soc. C. E.) to Peru, South America, in charge of the erection of the first Verrugas Viaduct, but was unfortunately prostrated by a low fever for several months, and rendered unable to do anything in connection with the bridge, but subsequently resumed engineering employment as Division Engineer of the Callao, Lima & Oroya Railroad.

Leaving South America in 1873, he made an extended tour in Europe, and 1875–76 was engaged as Principal Assistant Engineer under Messrs. Henry Pettit and Joseph M. Wilson on the Main Building and Machinery Hall of the Centennial Exhibition, and in this capacity worked out the details of some of the important construction connected with these buildings.

In 1876 he again went to South America as Engineer of the Southern Railroad of Chile, but his absence was of short duration, and he returned the same year, taking a position in the Water Department of Philadelphia, which he held until 1879.

In 1880 he accepted the position of Resident Engineer of the Richmond and Allegheny Railroad in Virginia, and following this was engaged in a general consultation and inspection practice until May, 1893, when he went for a third time to South America, taking for a period of six months the position of Municipal Engineer to the city of Guyaquil, Ecuador.

Mr. Cleemann wrote and published in 1880 a small volume entitled "The Railroad Engineer's Practice," a work which passed through three editions in four years, increasing in size with each edition. A fourth edition was issued in 1882, to serve as a text-book to a course of lectures delivered by him at the Rensselaer Institute in that year, when he temporarily filled a vacancy in the faculty. He also contributed, from time to time, sundry original articles and reviews on professional subjects to the various engineering magazines.

During the year 1887 Mr. Cleemann was President of the Engineers' Club of Philadelphia, and we all remember the faithfulness with which he attended to the duties of that office, as well as his devotion to the interests of the Club during the entire period of his membership, to which the records of the Club bear witness.

Only the day before the termination of his engagement at Guyaquil, November 9, 1893, he was attacked by what proved to be that dread malady—yellow fever. The faithful friend who stood by him through the sad conflict, has given a most touching account of the tranquillity and courage with which he bore his sufferings, until at the end of seven days he finally passed quietly away on the afternoon of November 16th.

All who came in contact with Mr. Cleemann must have been impressed with his marked characteristics of refinement, gentleness and culture, his wide professional experience giving weight to his opinions, which, being always clearly expressed in the most courteous manner, never gave offense to those who might hold different views.

The Engineers' Club of Philadelphia may well be proud of having had such a man as Thomas Mutter Cleemann so identified with its history, and the individual members may learn valuable lessons from so worthy an example.

ABSTRACT OF MINUTES OF THE CLUB.

Business Meeting, October 6, 1894.—President John C. Trautwine, Jr., in the chair. Forty-eight members and visitors present.

The minutes of regular meeting, June 16th, were read and approved.

The Tellers reported that the following gentlemen had been elected: Messrs. Harrison Souder, E. D. Graves, George F. Ott, Francis Schumann, G. C. Schoff, George C. Plummer and Alexander J. Christie to active membership, and Mr. William J. Hamlin to associate membership.

Resignations of membership were presented and accepted from Messrs. George McCall, William Ingles and John W. Cloud.

The Secretary read a circular letter and proposition from Mr. E. L. Corthell for the establishment of an International Institute of Engineers and Architects, the principal objects of which would be:

First.—To unite in closer relations all departments of engineering and architecture.

Second.—To furnish a suitable and convenient channel by which information relating to new discoveries, processes, methods, inventions and works may pass from one country to all other civilized countries of the world for the benefit of the profession and of mankind.

Third.—To conduct, by the assistance of the Fellows of the Institute, individuals and governments, systematic and thorough tests of all classes of materials used in constructive work, and to disseminate through the channel of the Institute the resulting information.

This proposition elicited much discussion, and a motion was made by Mr. Robert A. Cummings that a committee of three be appointed by the chair to consider the matter and report at a future meeting of the club. Carried.

The Secretary reported that during the summer the following deaths had occurred among our membership:

Mr. Thomas S. R. Flickwir, on July 12th.

Mr. Henry W. Dunne, Superintendent of the New York, Philadelphia and Norfolk Railroad, August 26th.

Mr. Samuel L. Smedley, ex-Chief Engineer and Surveyor of Philadelphia, on July 21st.

Upon motion, the Chair was requested to appoint committees to prepare suitable memorials.

Mr. Henry G. Morris, Chairman of the Committee appointed for the purpose, presented a memorial of the late Thomas M. Cleemann.

Prof. Silas G. Comfort, Chairman of the Publication Committee, announced that after careful consideration his committee had recommended to the board, and they had adopted a plan, to issue the Proceedings in the future in the months of January, April, July and November, each number to contain a complete record of all the Clubs' proceedings since the previous issue.

Mr. A. Falkenau, Chairman of the Information Committee, reported that a

party of forty, including eight ladies, had participated in the excursion to Reading (on June 30th), and that the programme, which had been arranged and sent to all members, was very closely carried out. Most of these arrangements were perfected by a local committee consisting of members of the Club and citizens of Reading, and, upon Mr. Falkenau's motion, the thanks of the Club were extended to that committee for the efficient management of the excursion.

Mr. Falkenau stated for the Information Committee that it was very desirable that members having papers to present should notify the Committee as far in advance as possible, in order that the programmes for the different meetings might be arranged.

The President reported that the French Society of Civil Engineers had sent to the Club and to certain of its officers and members of the Committee which arranged for the entertainment of members of the Society during their visit to Philadelphia last fall, copies of a souvenir lithograph and medals commemorative of their tour in this country during the year of the Columbian Exposition. The lithograph and silver medal sent to the Club will be framed and placed in our meeting-room.

The President also stated that the Civil Service Examining Board of Philadelphia desired it to be known that they were endeavoring to improve the character of the city engineering service by raising the standard somewhat, especially with regard to the class of applicants for examination, and the younger members of the Club especially who desired positions in the city's engineering corps should make application to this board for examination.

Prof. Walter L. Webb presented a paper on "Atmospheric Resistance."

Regular Meeting, October 20, 1894.—President John C. Trautwine, Jr., in the chair. Fifty-four members and visitors present.

The minutes of business meeting, October 6th, were approved as printed.

The Secretary announced the names of committees that had been appointed in accordance with resolutions passed at the last meeting, to consider the proposal for the establishment of an International Institute of Engineers and Architects, and to prepare memorials upon our lately deceased members, Messrs. Flickwir, Dunne and Smedley.

The President announced that through the generosity of the manufacturers, the chandeliers throughout the house had been equipped with Welsbach incandescent gas burners, which would greatly improve the illumination and ventilation of the rooms.

Prof. Silas G. Comfort read a paper on "Unit Stresses for Railroad Bridges of Wrought Iron."

The subject was discussed by Messrs. William R. Webster, Robert A. Cummings, W. C. Furber, C. H. Davis and F. Schumann.

Mr. A. L. Eltonhead's paper on "The Electro-Metallurgy of Gold and Silver," which was presented at the meeting of May 5, 1894, was re-read at his request, in connection with a supplement that he had lately prepared.

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

REGULAR MEETING, SEPTEMBER 15, 1894.—Present: President John C. Trautwine, Jr., Vice-Presidents James Christie and A. Falkenau, Directors W. B. Riegner, John L. Gill, Jr., Silas G. Comfort, Charles L. Prince and the Secretary.

The Minutes of Regular Meeting, June 16th, were read and approved.

The Treasurer's Reports for June, July and August showed:

Balance from May	$ 841 42
Amount received during June	271 75
	1,113 17
Amount expended during June	547 48
Balance on hand June 30th	565 69
Amount received during July	169 16
	734 85
Amount expended during July	587 66
Balance on hand July 31st	147 19
Amount received during August	219 75
	366 94
Amount expended during August	113 48
Balance on hand August 31st	253 46

The Secretary read a letter received from the Secretary of the Société des Ingénieurs Civils de France, and presented an accompanying vote of thanks with five copies of souvenir lithographic plate, containing photographs of delegates, etc., ane five souvenir medals, one of silver for the Club, and the others of bronze, respectively for the then President, the Secretary, and the two most active members of the Reception Committee; also a letter from Mr. O. Chanute, stating that he had received from the same society fifteen litographs and ten medals for distribution among the lately associated engineering societies, and asking information as to who were the most appropriate persons to receive these mementos. These two communications were referred for answer to the late Reception Committee.

The House Committee was directed to have the ventilation of the meeting room and the plumbing attended to, and to have the Club's copy of the French souvenir lithograph and silver medal framed for exhibit in the assembly room.

A circular letter from Mr. E. L. Corthell, accompanying a proposal to establish an International Institute of Engineers and Architects, was ordered to be referred to the Club at its next meeting.

The Membership Committee reported that they had now on hand seven new applications for membership, and the President ordered that the next meeting of the Club be a business meeting, in order to take action upon the applications.

The Publication Committee reported that in order to satisfy the postal authorities in the matter of getting our PROCEEDINGS admitted at second-class rates, which would make a saving of about fifty dollars per year in postage, it had been found necessary to alter the title-page, as per proofs submitted, which had also been submitted to Mr. Alexander, Superintendent of Mails at Philadelphia, who pronounced them satisfactory. The principal changes in the same are the statements that the PROCEEDINGS are published by the Board of Directors of the Engineers' Club of Philadelphia, and the change of the quarterly issues, so that the third number will appear in November instead of October, as heretofore. This title-page was approved by the Board, as was also the proposal to make the April issue the first number of a volume, and the January number the last, so that a volume would contain a complete record of the Club year.

Upon motion, the Chairman of the Publication Committee was authorized to allow other journals to republish Mr. Falkenau's paper on "The First United States Pneumatic Postal System" from the Club PROCEEDINGS.

A motion to discontinue the copyright on the PROCEEDINGS was discussed and lost, and upon further motion the Committee was instructed to insert in the PROCEEDINGS a notice inviting other technical journals to copy papers, provided they give due acknowledgment to the source from which such papers are obtained.

The Information Committee reported that forty members and their friends had gone on the Excursion to Reading, and that they had paid their own expenses; but that the Committee had spent $19.14 for badges, fans and three guests. Upon motion, a bill for these expenses was approved and ordered paid.

The Trustees of the Sinking Fund reported that only five members had requested payment of their two-year notes against the Club, and that there was now in the fund a balance of $233.72.

REGULAR MEETING, OCTOBER 20, 1894.—Present: President John C. Trautwine, Jr., Vice-President A. Falkenau, Directors John L. Gill., Jr., Edward K. Landis, Silas G. Comfort, Charles L. Prince and the Secretary.

The Minutes of Regular Meeting, September 15th, were read and approved after slight correction.

The President reported the names of Committees that he had appointed respectively to consider the proposition for the formation of an International Institute of Engineers and Architects, and to prepare memorials upon the late Messrs. Dunne, Smedley and Flickwir.

The Treasurer's Report showed:

Balance from August	$253 46	
Amount received during September . .	139 51	
		$392 97
Amount expended during September . .		130 67
Balance September 30, 1894		$262 30

The Finance Committee reported that there were September bills payable amounting to $232.00, and that they had ordered all of the smaller bills paid.

The Secretary presented a communication from Mr. T. Carpenter Smith, Chairman of the Finance Committee of the American Institute of Electrical Engineers, accompanying a check for $24.50, sent by direction of the General Committee, being half of the unexpended balance remaining after the Tenth Annual Meeting of the Institute, with the thanks of that party to the Club for the assistance it had given in entertaining visiting members. The Treasurer was directed to accept this donation with thanks, and to place it with the general funds in the Treasury.

The House Committee reported that the Welsbach Incandescent Gas Light Company had presented thirty-six burners to the Club, and mounted them on chandeliers in various parts of the house. Upon motion the Secretary was instructed to convey the thanks of the Club to the Company, for this valuable gift.

CONTRIBUTIONS TO THE LIBRARY.

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XVIII.

THE FILTRATION OF PUBLIC WATER SUPPLIES.

By HENRY LEFFMANN, M.D., Active Member of the Club.

Read, November 3, 1894.

IN the paper on the water supply of Philadelphia, read here two years ago, I referred to the beneficial effects on water by storage and filtration. So rapid has been the progress in this field that even in the brief interval a great deal of additional matter tending towards exactness has been developed. I propose this evening to explain briefly, and to illustrate practical methods of water-purification, methods which have been carried out on so large a scale as to leave no doubt of their entire applicability to existing engineering problems in this field.

Methods of filtration are quite numerous. They may be for purposes of consideration here arranged under two heads: those in which the water is subjected to some preliminary treatment by which more or less of a coagulum or precipitate is formed, which is subsequently entangled in the filtering material and by enclosing the living germs, prevents their transmission to the effluent. Such a process is strictly one of filtration in the laboratory sense

of the term; the filter acts practically as a mere straining agent, and although the entangled microbes ultimately die, it is not entirely in pursuance of a normal biologic action. The other method is to supply the water to the filter without previous treatment, and to rely not so much upon mere straining action, but to promote transformations similar to those in soil, by which organic matter is consumed, and rendered innocuous, while at the same time the microbes pass through the stages of development, age and death; the invariable sequence in living matter. Under proper conditions an effluent from such a filter will be continuously almost sterile.

For the first method of filtration, namely, that in which a coagulant is employed, we have several systems depending on the nature of the coagulant. As all these are tolerably familiar to engineers, I need merely indicate them, and briefly discuss their sanitary aspects. The most extensively employed coagulent is probably aluminum sulphate, which is either employed as such or in the form of alum. The chemical changes by which aluminum sulphate acts as a coagulant are quite simple. Almost all natural waters contain carbonates, principally calcium carbonate and magnesium carbonate, more rarely sodium carbonate. When these substances in solution are brought in contact with aluminum sulphate, an interaction takes place by which theoretically aluminum carbonate should be formed, but as this body is apparently incapable of existing in water at ordinary temperature, aluminum hydroxide, a gelatinous, almost transparent precipitate, is produced, while carbonic acid dissolves in the water. Aluminum hydroxide has a high affinity for many varieties of organic matter, rendering them insoluble by adhering to it. The organic matters of the water, at least those in solution, are precipitated by the aluminum hydroxide, and the mass so formed entangles all suspended matter, enabling a subsequent filtration through sand, even at considerable speed and under pressure, to completely remove the microbes. It is obvious that the success of this operation depends largely upon the presence of the carbonates above mentioned, or some equivalent bodies, to precipitate the aluminum hydroxide; and some waters might not be purified by the alum process, simply because they do not

contain sufficient material to decompose the aluminum compound.

In practice this process may be carried out on waters, to which it is adapted, by machinery automatically supplying a solution of alum, or aluminum sulphate. Usually from half a grain to a grain of the latter to the gallon will suffice. These methods are especially adapted for the purification of the supplies to large institutions or communities of moderate size; but I am not so satisfied of their adaptability on the very largest scale. Take, for example, the case of Philadelphia and suppose the average daily consumption to be 100,000,000 gallons, which is below the actual figures; at the rate of half a grain of the coagulant to the gallon we would have an employment of 50,000,000 grains, which by a rough calculation is shown to be over three short tons. While I think it is true that so small a quantity of aluminum compound could not be harmful, yet I believe if it were the general practice to introduce daily into the Schuylkill water three tons of chemical material, there would be a tendency to ascribe a great many vague stomach troubles to this practice; doctors unable to determine the cause of various maladies would be too ready to make the excuse that it was the alum in the water.

Some years ago Mr. Devonshire gave to the Club a full account of the iron process of water purification, in which a coagulant analogous to that in the alum process is used, but in which the precipitation depends more completely upon the coagulant itself and does not involve the necessity for any particular mineral ingredient in the water. Briefly, I may say the water is agitated with fragments of iron, and by the action of the dissolved oxygen and carbonic acid, ferrous carbonate is formed, which is suspended in the water in the form of a very fine dark-green precipitate. On aërating the water by allowing it to flow in more or less of a cascade, the ferrous carbonate absorbs oxygen and water and loses carbon dioxide, passing into the condition of ferric hydroxide, a substance analogous to aluminum hydroxide and like it capable of combining with organic matter; this material entangles the suspended matter and the mass is then easily caught upon the surface of the filter. It will be seen that these changes involve the presence of no other ingredients in the water

except dissolved oxygen and dissolved carbonic acid, substances which are invariably present in notable amounts in natural waters. This iron process, therefore, is probably more widely applicable, especially to decidedly turbid waters, than any other precipitation method.

Iron compounds, for instance, ferric chloride (chloride of iron), may be added directly to water in the same manner as aluminum sulphate; but this method is more particularly employed in the purification of sewage, which I do not propose to discuss here.

I turn now to the discussion of filtration without previous treatment with chemicals. It is now generally admitted that the diseases conveyed by water are produced by living organisms, and that if we remove these living organisms, the water will be safe. In the previous paper to which I have referred, I spoke briefly of the nature of the germ of what is by far the most important water-borne disease (typhoid fever). I am more strongly convinced than I was then that the recognition of this germ is doubtful in many cases, and that it is not yet proved that a specific organism has been recognized as the sole cause of typhoid fever. Whatever may be the truth in this respect, and a discussion for my reasons of this view would not be appropriate here, we may take it for granted that when water is contaminated by real sewage it is liable to convey fatal disease, and this conveyance is by means of microbes. It may be worth while to say in passing that mining or manufacturing refuse proper, except when it introduces poisonous metallic substances, such as lead, arsenic or copper, is of very little sanitary moment, and that quite simple systems of subsidence or straining will rid the water of the objectionable materials. We cannot, however, depend upon so easily removing the living microbes, and when there is discharged into a fairly pure stream, a small amount of infected sewage, the opportunities for multiplication of the living microbes are greatly increased by the dilution, for they have more room in which to develop. Hence we find that very small amounts of pollution will seriously affect large streams.

The chemistry and biology of filtration processes have been so thoroughly elucidated of late years, and have such an important

bearing practically, that I must briefly discuss the matter. The organic matters in water, under which term we include a great variety of material, living and dead, derived directly or indirectly from plants or animals, are incapable, under natural conditions at least, of remaining permanent. As soon as a particle of tissue or any soluble organic matter from an animal or plant enters water or soil it becomes the prey of microbes and breaks down into simpler forms. The sequence of these transformations has long been known, having been especially studied in connection with agricultural problems. The dangerous organic matters of water contain nitrogen, and are first converted into ammonium compounds, and finally, by oxidation, into nitrates, often with an intermediate stage of nitrites, though these are rarely present in more than minute amounts. Left to itself, therefore, a polluted water passing through soil will gradually be completely purified, its organic matter will be converted into nitrates, and will become in this way unsuited to the nourishment of dangerous microbes, and these therefore will perish. If we look around us, therefore, observing the natural conditions, we see that subsoil water represents the highest grade of purification when the conditions are at all favorable to natural changes. Rain water, for instance, is always more or less impure; surface water is subject to serious pollution in populated districts, and as long as it remains surface water is very slow to purify itself, while deep or artesian water frequently comes to us, showing evidence of decided pollution, but as this belongs mostly to a remote geologic period we assume with safety that the microbes are all dead. Well waters, when not contaminated by surface drainage, or polluted by direct flow of contaminated water through the crevices of the soil, are rarely capable of conveying disease, and some carefully conducted experiments have shown that when wells are protected from the entrance of microbes from the air and only the water is present which is passed through compact soil, it is practically sterile. It is by applying these principles in the construction of filters that the best results have been obtained. The experiments of the Massachusetts State Board of Health, which are so frequently referred to in discussing this question, have clearly established that our most satisfactory methods of water purification are to

be obtained by making the filters represent the soil. The experiments of this Board have covered a question of sewage purification as well as the purification of slightly sewage-polluted water. In the former case great success has been obtained by the employment of what is known as the intermittent system, the flow of sewage on to the filter being interrupted at regular intervals, the filter allowed to drain, by which air enters its pores ; the organic matter caught upon the surface of the sand-grains is oxidized, and when this has been accomplished fresh material may be passed through. This alternation of charge and discharge may be kept up for a long while. It is found, however, that if the rate of filtration be slower, the intermissions may be less, and in this way it is possible to maintain a continual system of filtration, interrupting the process only for a moderate amount of filter cleaning.

We owe to the Massachusetts investigators much valuable information as to the chemistry and bacteriology at various points in the filter, as to the effects of rate of speed, and especially as to the size and character of the sand-grains ; it appears that a rather fine and somewhat angular sand is most suitable. It is not unlikely that the chemical composition of the materials adherent to the sand, especially the presence of iron oxides, has considerable influence upon the efficiency of filtration, and some experiments that I have been making lately seem to show that a soil rich in iron oxide has especially high filtering activity. I have placed in the room a small model filter containing this material, that the members may see the work it does. A sketch of the construction of the filter is also shown ; it is a very convenient arrangement for experimental filters, and was shown to me by Mr. Devonshire, who first saw it in the laboratory of Prof. Kemna, at Antwerp.

Simple sand filtration, therefore, is a process entirely satisfactory for the purification of public water supplies. It is especially adapted to the needs of large cities located on streams which are the drainage channels of a populated water-shed. Such streams form the natural and most convenient sources of supply for the cities through whose limits they pass, but it is equally true that such streams are almost invariably dangerously con-

taminated. We have hundreds of examples in this country and many in Europe to prove this point. We need not go further than our own city to note the effect of drinking a moderately polluted water. Without desiring to make this discussion of merely local interest, I wish to exhibit here a map which I prepared from the official records of the Board of Health, showing the distribution of death from typhoid fever in this city in 1893. It will be noted that a very large number of deaths occurred in the district north of Callowhill, south of Lehigh Avenue and west of Broad, a district which has long been on what is called the direct distribution, the water being pumped from the river into the mains without opportunity for that moderate degree of improvement which follows subsidence. It will be seen that the district from South Street clear up into the northeastern part of Kensington, which is supplied by the water from the East Park Reservoir, is far less subject to the disease, although the sanitary conditions, other than the water supply, are decidedly inferior to the first district mentioned. The district below South Street, supplied from Fairmount, a small basin, giving probably but little storage, is very seriously affected by the disease. It is also worthy of note that Girard College, which is located in the heart of the direct pumpage district, is almost free from typhoid fever, although it has a population of nearly 2000. All the water supplied to this institution is filtered.

In conclusion, I may say therefore, that the filtration of public water supplies is no longer in an experimental stage ; that by imitating the natural processes the destruction of organic matter by microbes and the destruction of microbes themselves we can render even a highly polluted water perfectly safe. Surface water should always be so treated unless an engineering inspection shows absolute freedom from pollution with sewage. Operations on the large scale are now sufficiently numerous to indicate that what holds good in the laboratory will hold good in the largest filters, and the experience of Poughkeepsie indicates that even the winters of our northern climates do not militate against the use of this method.

With a view of illustrating to the Club the practical operations of filtration I have arranged to exhibit by the lantern a few

slides kindly made for me by Mr. Prince, to whom I wish to express my thanks. No doubt these views are familiar to some, but will probably be unfamiliar to most present.

I am also able, through the kindness of Mr. George W. Fuller, Biologist of the Lawrence (Mass.) Experiment Station, to show you samples of the standard sands used there. Doubtless the rather coarse grains in some of the samples will excite remark, but it has been found that by a judicious association of oxidation and filtration even these coarse sands may be made efficient.

In a recent communication Mr. Fuller points out that the observations at Lawrence have shown that the disease-producing microbes die at the top of the filter, being apparently less fitted for the struggle than the microbes normal to the water. In fact, there is some reason to believe that some of these disease-producing microbes, for instance the typhoid germ, are but highly differentiated or specialized forms of ordinary water bacteria, and, like other wide departures from the normal, are unable to sustain a severe competition. The observations at Lawrence, therefore, fairly dispose of one objection to filtration. It is often said that if five out of 1,000 microbes pass through the filter these five may be the very ones that are dangerous, but we see that this is not likely to be the case.

The following account of the method of constructing filters for sewage purification has been furnished me by H. W. Clark, Chemist at the Massachusetts Station.

The sands in use in the large filter vary in effective size from .04 to 1.40; that is to say, the finest 10 per cent. of the material is composed entirely of grains whose diameter is less than .04 of a millimeter in the finest material used and less than 1.40 millimeters in the coarsest.

With coarse and medium fine sand the filters contain but one grade throughout the entire five feet. With fine sands trenches are sometimes dug one to two feet deep, and filled with coarser sand; this gives a given area greater filtering capacity.

With what we consider the best grade of sand the applied dose of sewage, 100,000 gallons per acre per day, will pass below the surface of the sand in a time varying from 10 minutes to 1½

hours, depending mainly on the condition of the surface of the filter. The remainder of the twenty-four hours the surface is uncovered.

In the intermittent filtration of water as now practiced at this station the surface of the filter is uncovered two hours out of the twenty-four.

DISCUSSION.

Mr. Edward K. Landis asked for information as to the efficiency of the process of electrolyzing sea-water.

Dr. Leffmann.—This method is for the purification of sewage, and is not applicable to water supply. It is also suitable for the disinfection of garbage.

Dr. Albert R. Leeds.—In the work of the Water Commissioners of Philadelphia, from 1881 to 1884, when they covered the ground so thoroughly, they considered the source of supply from the Delaware River and tributaries, Perkiomen, Tohickon, and the entire country drained by the Schuylkill River; also the possibility of a subterranean supply. That the decision to retain the Delaware and Schuylkill as the sources of supply was right in 1884, is more than confirmed at the present time. Our knowledge of bacteria at that time was limited. The origin of cholera and typhoid had not been established, and only within the last three or four years has it been possible to remove actual particles of matter by filtration. In the laboratory, the germs are eliminated by filtering them out. For this reason I advocated a purification of the Schuylkill and Delaware for the future water supply of Philadelphia.

Philadelphia is a typhoid city. London was a cholera city. The great epidemic of London was due to the water supply. By act of Parliament, in 1850, the seven water companies were compelled to filter their water supplies. The report of the Water Commissioners at that time was the most important and complete ever made. They examined every possible source within 150 miles, and even considered a supply from Wales. At the conclusion of their labors their decision was not to abandon but to purify and filter. At the present time the water of the upper Thames is receiving more sewage than the Schuylkill, but fil-

tration is amply able to take care of it, and instead of being a cholera or typhoid city London is fortunate in having the lowest rate of typhoid, as it is now almost stamped out of the city.

The fact that filtration affords the only guarantee of safety is recognized in every engineering plant in England. About ten years ago a new system was inaugurated, which is purely American. Experiments were made with the mechanical and chemical systems. In one system, instead of open filter beds, closed cases of steel are used, having a capacity of 250 pounds pressure per square inch, and instead of removing impurities from the beds by the scraping process they are removed by reversing the current. Such a plan is impossible by the English system, as the beds must be done in *toto*.

Bacteria cannot be removed by ordinary filters. In the English and German processes bacteria are removed by the formation of a thin membrane on the rough surface. It has been shown that the bacteria secrete and form a membranous slime. The temperature is a very important factor, but it takes from three to five days for this membrane to form; therefore, whenever a bed is cleansed, from three to five days must be allowed for this skin, which is really the filter, to form. At the Antwerp station, where the iron compounds were used, the plant is so large that it is generally valueless, as the application is limited.

The fact that alum purifies water has long been known, and during the war in Tonquin the French soldiers were compelled to use this method.

Mr. John C. Trautwine, Jr., then made some remarks concerning the intermittent system in London.

Mr. Robert A. Cummings pointed out that the percentage of bacteria retained by the filter beds of Lawrence and London was practically the same, and inquired the reason for the higher typhoid death-rate of Lawrence. He believed the habits of the people had a great deal to do with the typhoid death-rate. This was evident by noting the low typhoid death-rate of some German cities, notably Munich, the largest beer-consuming city of the world, and one of the most free from typhoid fever, the consumption of beer amounting to 125 gallons per capita per annum.

Dr. Leeds replied that the great pollution of the Merrimac River was due to Lowell, but that since the introduction of filter beds, there had been no case of typhoid fever except among the mill-hands who drink the water directly out of the canal.

Dr. Leffmann.—In American cities, typhoid is spread through milk and food raised on truck-farms. The typhoid epidemics of Massachusetts were directly traceable to the milk supply and other local causes. In London the milk is sterilized.

Mr. John Birkinbine.—The water supply from the Schuylkill valley is so thoroughly bad from different causes, that, strange to say, it in a measure purifies itself. The acids from the coal mines kill the microbes from the sewage. I believe that in future Philadelphia will be supplied with water by gravity, and the entire drainage area will have to be controlled. If the water supply is to be filtered it should be filtered at the source. Philadelphia does not use anything like the water that it gets credit for. This does not come from any intentional error, but from wrong calculations as to the stroke and capacity of the pumps.

Mr. James Christie spoke of the breaking out of fever and ague after the canal was built along the Schuylkill, and its subsequent disappearance, which was supposed to be due to the agitation of the water. He also spoke of the effect of snow water on the people of Switzerland and lime-water on the people of Scotland in enlarging the glands of the neck.

Prof. Walter L. Webb called attention to a double system of water supply advocated by Mr. J. W. Hill at the meeting of the American Society in Chicago.

Mr. S. E. Moore spoke of the intermittent water supply in London, and stated that what is needed here is better water instead of so much of it.

Mr W. C. Furber stated that the Carnegie Company, for their office building in Pittsburg, sterilize the water and charge it with carbonic acid gas.

XIX.

HIGHWAY IMPROVEMENTS IN PHILADELPHIA.

By George A. Bullock, Active Member of the Club.

Read, November 17, 1894.

When considering the improvements that have been made recently in the highways of other cities, it is well for us, as members of the Engineers' Club of Philadelphia, not to lose sight of what has been done in this direction in our own city. It is, therefore, my desire this evening to present a condensed statement of the recent changes that have taken place in the highways of Philadelphia.

The total number of miles of streets and roads open and in use in the city are 1,325, divided as follows:

Streets paved	869 miles
" unpaved	426 "
Turnpikes	30 "
Total	1,325 "

The pavements at present on these streets have been put down under various ordinances of the City Councils. These ordinances are of interest, as showing the advancements that have been made in our street paving legislation.

The ordinance of the 3d of May, 1855, provided that the cartways of the public streets and highways of the City of Philadelphia (except at the intersections thereof), shall be paved at the expense of the owners fronting thereon, and the repairing of the same shall be done at the expense of the city.

At that time the owners of property, or a majority, could select the kind of material—the contractor to do the work in accordance with specifications prepared by the Chief Commissioner of Highways.

The ordinance of the 12th of June, 1868, provided that the sum for cubical block paving shall not exceed three dollars per square yard. The ordinances of the 24th of April, 1877, provided that the cost for the new paving of the cartways to be charged to

the owners of property fronting on such streets, and to the city for intersections, shall not exceed the following: for paving with cobble stones, one dollar per square yard; for paving with rubble stones, one dollar and ten cents per square yard.

The ordinance of the 12th of June, 1868, contained the following provisions: "All streets having a width of fifty feet and upwards within the area bounded by the south side of Tasker Street on the south, the south side of Girard Avenue and Shakamaxon Street on the north, the Delaware River on the east, and the Schuylkill on the west, that may require paving or repaving, shall hereafter be laid with cubical blocks of such material as shall be approved by the Chief Commissioner of Highways, with a depth of five inches, from four to six inches long, and from two and one-half to three inches wide." This appears to be the first record we have of any action of Councils to specify the kind or size of material for street paving. The cobble stones and rubble previously used varied from a marble to an ordinary one man stone, and I have removed from some of our streets, boulders of such size that three men could not even lift one of them.

In the old portion of the city, on Ninth Street, between Spruce and Walnut Streets, the smaller cobbles were placed next to the curbs, and the center of the street was paved with large boulders. Some of the old residents on the street informed me that this pavement had been laid fifty years before, and that the street had been disturbed only for the purpose of making sewer or water connections; also, that the main body of the street was as it had been originally paved. This renewal of Ninth Street was made in 1864, and the large stones were sold to pavers for use on the new streets in the suburbs, as they were too large to be used in repaving.

It was not until December 12, 1881, that an ordinance was passed making it unlawful to use cobble or rubble in the paving of any street in the city, or to pave any gutter with brick. There was, however, a proviso in this ordinance that it should not apply "between the tracks of any passenger railway, nor shall it affect existing contracts."

The change from block to asphalt paving, and the consequent transformation in the condition of our streets during the last

two years, has been due to legislation made by City Councils. As a partial compensation for valuable franchises the passenger railway companies have been *obliged* to pave most of our principal streets, and as a result they are now in excellent condition.

According to a statement made out in September and October of the present year, 1894, the number of miles of single track operated by the passenger railway companies is as follows:

Philadelphia Traction Co.	180	miles
Electric Traction Co.	129	"
People's Pass. Ry. Co.	53.64	"
H., M. and Fmt. P. Ry. Co.	20	"
Total	382.64 miles	

The estimate of the amount of improved pavements and macadamizing for the years 1891, 1892, 1893 and 1894 is as follows:

NEW PAVING PUT DOWN BY CITY.

	Square Yards.	Linear Feet.	Miles.
1891	417,935.96	131,944.00	25
1892	350,355.16	118,695.00	23
1893	266,418.86	90,931.06	17
1894	392,000.00	148,000.00	28
	1,426,709.98	489,570.06	93

REPAVING WITH IMPROVED PAVEMENT BY CITY.

1891	174,342.60	65,567.00	12.4
1892	295,014.75	107,743.00	20.4
1893	439,406.08	180,389.09	34.2
1894	219,819.00	90,000.00	17.0
	1,128,582.43	443,699.09	84.0

NEW MACADAMIZING BY CITY.

1891	74,900.00	34,344.00	6
1892	47,503.00	19,729.00	4
1893	148,059.23	80,086.80	15
1894	175,000.00	100,000.00	19
	435,462.23	234,159.80	44

REPAVING WITH IMPROVED PAVEMENT BY PASSENGER RY. CO'S.

	Miles.
1891, 1892, 1893	50
1894 (estimated)	110
Total	160

Another improvement which has been gradually carried forward is the rounding of all street corners. Before this was done a team could not turn the sharp corner without the horses running into any other vehicle that might be on the track in the middle of the street.

To improve the small streets which are still paved with cobble and rubble will cost from $15,000,000 to $17,000,000, but it is thought that gradually the money will be appropriated, and the work can be done, for Philadelphia is not poor, as its public buildings, bridges, parks, water and gas works will attest, and although the city has been charged with bad management there are few business enterprises that can show more for the same amount of money expended than is evident in our public work. Comparisons with Berlin, in Germany, where private corporations run nearly all of the public business, show that the city's financial condition is not as good as ours.

SOME OF THE RESOURCES OF THE CITY.

Length of Bridges, 35 miles, costing $15,000,000.

Number of Bridges over 8 feet span, 320.

Miles of Water Mains, 1,100.

Number of Reservoirs, 22.

Water capacity, 230,040,000 gallons per day. Average pumpage, 180,000,000 gallons per day.

Miles of Gas Mains, 1,140.

Number of Gas Holders, 23.

Annual production, 3,803,316,000 cubic feet.

Number of Meters in use, 148,265.

Number of Gas Lamps, 21,797.

Number of Gasoline Lamps, 9,519.

Number of Electric Arc Lights, 5,500.

Miles of Sewers, 612.

Area of Philadelphia, 129,383 square miles.

Number of Buildings, 250,000, with 121,000 owners.

Assessed valuation, $782,677,694.00.

Receipts from Taxation, $25,697,468.90.

Number of Public Schools, 430.

Area of Fairmount Park, 2,648 acres.

Area of Schuylkill River in Fairmount Park, 275 acres.

Area of small Parks, 373 acres.

Water front, 32 miles.

Total amount of indebtedness of all descriptions, August 1, 1894, was	$57,458,045 22
Less Sinking Fund holdings	25,390,021 63
Total net indebtedness, August 1, 1894	$32,068,023 59

Assessed valuation of real estate owned by the City of Philadelphia, except Water Bureau, Gas Bureau, and Fairmont Park	$28,154,255 00

Or nearly enough to pay off the whole of the net indebtedness.

This property is worth at least twice as much as it is assessed for, and, in addition, the city has the Gas works and franchises, which, at prices repeatedly offered, are worth at least $25,000,000; it has the water system, which is worth an equal amount, and, in addition to both of these, Fairmount Park, which is certainly worth at a low estimate an additional $25,000,000, or total estimated assets of $100,000,000, against an indebtedness of $32,000,000, while on the first day of January next the debt will be further reduced by several millions of dollars.

Notwithstanding the expenditure of vast sums of money during the past few years for permanent improvements, part of which has been raised by loans, there has been a steady decrease in the net debt of the city, and a steady increase in its assets.

MILES OF PASSENGER RAILWAY TRACKS.

Philadelphia Traction Co.	180 miles.
Electric Traction Co.	129 "
People's Traction Co.	62 "
Hestonville, Mantua and Fairmount Pk. Ry. Co.	20 "
Wissahickon Electric Passenger Railway Co.	5 "
Manayunk Inclined Plane and Railway Co.	7 "
Total	403 "

MILES OF STEAM RAILROAD TRACKS.

Pennsylvania Railroad Co.	371.24 miles.
Philadelphia and Reading Railroad Co.	248.77 "
Baltimore and Ohio Railroad Co.	44.50 "
Total	664.51 "

RECEIPTS FROM PASSENGER RAILWAY CO'S.

Car Licenses	$61,357 99
Taxes on Dividends	77,939 75
Total	$139,297 74

Our street-lighting system is probably now the best in the world. Not long since a delegation was sent from Paris to inspect it with a view of copying some of its details. Our new building law, although not perfect, contains many improvements over the old law, one of the most important of which is prohibiting the projection of bay windows or fences beyond the building line.

In conclusion, the great trouble in maintaining our highway improvements is the want of legislation assigning to some distinct authority the duty of enforcing the laws which are already in existence. Old abuses are, however, gradually being done away,

and the time is near when Philadelphia will be one of the best lighted, best paved and best managed cities in the world, as it now has the proud distinction of being the one where most citizens live in their own houses.

DISCUSSION.

Mr. Robert A. Cummings.—I have noticed that in the city of Baltimore asphalt blocks appear to be much used in street paving. Why are they not used here?

Mr. Bullock.—We have about nineteen miles of streets paved in this way without concrete foundation, and it has been found that the blocks rot at the bottom on account of capillary attraction of the moisture from the soil. With proper foundation, however, these blocks make an excellent pavement.

Mr. Edward K. Landis.—How does the cost of the electric light, gas and water compare in Berlin with those necessaries in our city?

Mr. Bullock.—Gas differs only two cents per thousand, and in other matters the two cities show wonderfully close comparisons.

Mr. Thomas G. Janvier.—How about the cost of street paving and maintenance?

Mr. Bullock.—Their paving costs about the same as ours, and they spend out three times as much for maintenance, but the work is done correspondingly better.

Mr. Henry G. Morris called attention to some instances of neglect of municipal orders and of street work paid for by citizens and badly done, which seemed to show the need of greater power for heads of public departments and for correlation of authority between departments.

Mr. George S. Webster.—The time of the Chief Engineers in the Survey and Highway Departments is taken up largely with problems of this kind, in which, for the lack of greater power, it is often difficult to correct abuses.

Mr. James Christie called attention to the advantages of brick paving in being noiseless, easily cleaned and easier to travel on grades than most other kinds that had been tested for crushing strength and gave the figures resulting from these tests.

XX.

SPECIFICATIONS FOR PORTLAND CEMENTS AND CEMENT MORTARS.

By Frederick H. Lewis, Active Member of the Club.

Read, December 1, 1894.

For a year past a number of questions regarding cements and cement specifications have been agitating the local cement world, and there has been much informal discussion. Some of these questions have been discussed before the American Society and also at the International Congress of Engineers at Chicago last year.

It has seemed to me, therefore, that a formal discussion of cement specifications before the Engineers' Club would be appropriate at this time. The Information Committee have accordingly placed before the Club advanced copies of specifications which I have prepared for purposes of discussion.

It is not my intention to suggest that these specifications be approved by the Club, or to urge their adoption by anybody. It is felt that every man is entitled to his own specifications; and the best practice in preparing them is to hunt up three or four specifications to crib ideas from, and then patch these together to form a new and "original" specification. As the other specifications were probably prepared in exactly the same way, the result in each particular case can hardly fail to represent the boiled-down wisdom of years.

It is my purpose to speak first of specifications and tests in general. After that to discuss the clauses of the specifications and then to resign the floor to those who may wish to debate them.

There is a prevalent impression among those who have to meet specifications for the reception of materials, that many of them are not well considered; that they do not provide tests which are practicable and desirable, and that many of them fail to cover requirements which are really advantageous. There can be no

doubt that in many cases such criticisms are well founded. There are tests for many purposes; there are tests made for information to ascertain certain facts in regard to the properties of materials; there are tests for research to ascertain the causes of certain phenomena, and there are tests for the regulation of products.

But when it comes to preparing requirements for the reception of materials, such tests as these just enumerated are out of place. It is impossible to prepare an intelligent specification without knowing the general character of the material, the causes of certain phenomena which it exhibits, and the general regulation required to produce it. This knowledge must be presupposed.

Again, there is a disposition in specifications to adopt new requirements and to push them to extreme rigor without having ascertained whether they are really advantageous. For example, some engineers insisted for years in requiring 52,000 pounds ultimate strength in bar iron. Certain mills were able to produce such iron, and the apparent advantage of it led to the adoption of this as a requirement. But we now know that 52,000 pounds ultimate in most cases meant 0.2 per cent. phosphorus in the iron, and that we should have been better off if the high ultimate had not been required.

Similarly, when steel was first introduced for structural purposes, the great advantage of the high ultimate strength was the feature which most impressed engineers, and they began by requiring steel having an ultimate strength approaching 100,000 pounds per square inch; but ever since that time we have been steadily but surely working back to a steel approaching the qualities of wrought iron, with an ultimate strength close to 50,000 pounds per square inch.

There have also been requirements introduced in specifications for the purpose of limiting competition. Certain manufacturers, having found that they could produce certain characteristics in their regular product which others did not regularly attain, have suggested and urged these things as requirements in specifications. This has been done in steel specifications and also in cement specifications, and from the manufacturers' standpoint there is no objection to his securing this

advantage if he can; but there is no reason why engineers should fall in with this sort of thing unless they are well assured that they are gaining some material advantage by doing so.

I wish to suggest as a broad principle in preparing specifications for the reception of materials, this: Frame requirements to cover an essentially good article, and then add nothing whatever to limit competition or advance the price. It logically follows that specifications drafted on this principle should contain no requirements which are not intended to be enforced, and none for which a satisfactory reason cannot be given.

What is a test and what does it mean? In my judgment there are no more important questions at present before engineers than these two. A test to be of value must, first of all, be entirely fair in its selection, in the method of its preparation, and in the methods of testing. Yet we find numerous specifications for the reception of materials which are full of stringent requirements, but are entirely silent on the question of conditions. In specifications for steel and in specifications for cements we may often find not two or three requirements, but from seven to ten; and yet these specifications will say nothing whatever in regard to the methods to be followed in selecting specimens, in preparing them or in testing them. The result has simply been this, that when a manufacturer receives specifications with rigid requirements but free from conditions, he selects the conditions which will best suit him to obtain the results. Tests obtained in this way are experiments pure and simple, and have no value as criteria of the essential qualities of the material.

In testing cements it is especially desirable that the conditions of fairness should be observed. From its nature there is no testing in which the personal equation counts so largely as in the testing of cements. Not only the skill but also the mental attitude of the operator can not fail to affect the results. For this reason I am strongly in favor of making the preparation of briquettes an entirely separate function from the sampling of the cements. This is done in all the testing for the city of Paris, and I believe it is also the practice at the Government Boards in England. In Paris the cement is handed in to the operator who

makes the briquettes by a number, and he does not know what it is, or where it came from until his work is completed.

So much for the conditions of tests. If we suppose then that a test of material has been fairly made in all respects, then the second question arises, what does this test mean? How much or how little does it signify? To many men a test of this kind has all the verbal inerrancy of the Presbyterian's Bible; and, if anything subsequently occurs to indicate that the material is not in all respects like the test, their faith in all testing is shaken.

Now a test is not an absolute fact, but a related one. It is in fact the minor premise of a syllogism. We have on the one hand a great mass of tests previously on record; this is the major premise. We have then the test just made, which is the minor premise; and lastly, a conclusion based on the relation of the two premises.

It is impossible to claim more than this for a test, because experience shows us that if we cut a piece of metal for instance, entirely into test pieces, we never get exactly the same result from any two specimens, or, if we take 100 samples from a single car of cement, we shall never exactly duplicate results. No material is perfectly homogeneous; some of it is quite unhomogeneous.

It is for this reason that we can much more readily say that material is bad, than we can assert it to be certainly good. Given certain results, we can say assuredly that the material is not good or not up to standard: but given, on the other hand, satisfactory results, we can not so confidently state that the material must be good or must all of it be good. We are dealing with the law of probabilities. We can simply say that the chances are 9 out of 10 it will be good, or 99 out of a 100, depending on the amount of information and skill we bring to bear on the testing; but the odd chance which prevents the certainty will always remain and cannot be eliminated.

If it is true that tests are not absolute facts, and that we can not draw absolute conclusions from them, the question may be asked what is the use of tests at all? I hardly think it necessary to answer this question at any length before the present audience. It is a fact worth stating, however, that the advantages of testing

are essentially mutual. The testing which one man does results to the advantage of others, and vice versa. The more regular and continuous the testing, the greater the uniformity and improvement in the product.

In order to show the reasonableness of certain requirements in the draft of specifications, I have prepared a series of tables, giving the results of tests made by me, or under my direction, and which will now be submitted. The tables have been prepared solely for the purposes of illustrating the specifications, and for this reason are limited to seven-day tests. On many of the samples tested, I have long-time tests, but as they have nothing to do with illustrating the specifications, I do not give them.

TABLE I.

COMPARISON OF 1 AND 7 DAY TESTS NEAT.

1 Day Neat.	7 Day Neat.
179	444
170	589
171	554
200	
170	444
285	590 (discard)
133	624
201	555
281	592 (discard)
164	756
128	564
201	612

One of the features of the specifications is a requirement that tests at one day neat shall not exceed 45 per cent. of the tests at seven days neat. Table I above gives a comparison of one and seven day tests and shows two cements which would be discarded under this requirement. There is nothing novel in a requirement which establishes a relation between tests at different periods. The specifications of the *Ponts et Chausées* in France require certain increases in strength at different periods, and Mr. Faija in England has suggested certain relations between three and seven day tests. As a rule the cements which mature rapidly are treated cements, and it seemed to me that this rapid hardening, producing a brittle, glasslike texture, was a disadvantage, and sacrificed that valuable property of Portland cements, by which they continue to gain strength and hardness through sev-

eral years' time. I have tested cements which had practically attained their maximum strength neat at seven days.

TABLE II.

UNTREATED CEMENTS.

7 Day Neat.	7 Day 3 to 1.
444	169
521	
568	175
554	218
468	
	142
528	156
464	167
444	177
441	213
502	110 (coarse)
450	194
373	
343	
494	142
467	67 (coarse)
589	170

TABLE III.

TREATED CEMENTS.

7 Day Neat.	7 Day 3 to 1.
590	253
624	194
612	191
550	253
555	223
545	199
565	218
719	237
514	220
601	176
915	334
579	201
592	205
756	232
692	242
564	238
705	255
735	218
709	229
706	232
695	183
707	189
505	191
558	197

Tables II and III above, are given to show the reasonableness of the test requirements at seven days. It will be seen that at seven days neat, the untreated cements have met the requirements

in every instance but one, and this one I do not think a good cement. It has been held that an untreated cement which gave 300 pounds at seven days should be satisfactory, but in the hands of a skillful operator, a cement which will show only 300 pounds at seven days neat, is in my judgment either underburnt, or else too fresh, and approaches too nearly to what are known in this market as the "improved" cements. When freshly ground the cement will probably show 300 pounds or a little more, but at the end of two or three weeks' seasoning it should show 375 pounds unless it is underburnt.

At seven days 3 to 1, the requirements have not been met so satisfactorily. There are two cements which are otherwise good, which fail to give 150 pounds, and the coarsely ground cements also fail. It may be that the requirements are a little high for sand tests in untreated cements, though I really believe that these requirements can be readily met by a sound cement in proper condition.

From table III it will be seen that all the treated cements listed have fully met the test requirements given, which are if anything low rather than high. They were made so in order that there should be no excuse for adding too much sulphate.

TABLE IV.

(A) Effects of Treatment with Sulphate of Lime.—An American Portland Cement Treated with Plaster of Paris.

	7 Day Neat.	7 Day 3 to 1.
As sampled	444 lbs.	196 lbs.
Plus 1½ per cent. sulphate	589 "	212 "
" 2 " " "	651 "	215 "
" 3 " " "	729 "	225 "
" 4 " " "	524 "	165 "
" 5 " " "	247 "	66 "
" 6 " " "	254 "	63 "

A gain by addition of 3 per cent. sulphate of 64 per cent. neat and 15 per cent. 3 to 1.
1 per cent. of plaster of Paris contains 0.55 per cent. of sulphuric acid (SO_3).

TABLE V.

(B) Effects of Sulphate.—Same Cement Treated with Anhydrous Sulphate.

	7 Day Neat.	7 Day 3 to 1.
As sampled	444 lbs.	196 lbs.
Plus 2 per cent. calc. sulph.	647 "	
" 4 per cent. " "	663 "	148 "
" 5 per cent. " "	293 "	127 "

1 per cent. of calcined sulphate contains 0.59 per cent. of sulphuric acid (SO_3).

TABLE VI.

(C) EFFECTS OF SULPHATE.—SAME CEMENT WITH PULVERIZED GYPSUM.

	7 Day Neat.	7 Day 3 to 1.
As received	444	196
Plus 2 per cent. gypsum	673	
" 3 " " "	541	179
" 4 " " "	533	194
" 5 " " "	593	179

1 per cent. of gypsum contains 0.465 of sulphuric acid (SO_3).

In tables IV, V and VI are given a series of experiments to show the effect of adding sulphuric acid in various forms to Portland cements. In table IV sulphuric acid was added in the form of plaster of Paris or boiled plaster, which contains one-half molecule of water of crystallization. In table V, to the same cement, sulphuric acid was added as calcined or anhydrous sulphate of lime. In table VI, the sulphuric acid was added to the same cement in the form of ground gypsum, or sulphate of lime, containing two molecules of water of crystallization. This series of tests was made to show that the effect produced is due to sulphuric acid, and is not due essentially to any of the properties of the added substance which contains it. In other words, if plaster of Paris is added the effect is not produced by the properties of plaster of Paris, except just this far: that in plaster of Paris the sulphate is in what may be called a nascent condition, and the reaction, therefore, takes place more rapidly than in the case of calcined sulphate or gypsum. On the other hand, it would appear that when the sulphuric acid is added in form of gypsum, the injurious effect is less apparent than that produced by an overdose of plaster of Paris.

This cement, and the others experimented with below, contained before treatment about 1.00 per cent. of sulphuric acid (SO_3) in the form of calcined sulphate, which is due to the fuel used in burning the clinker.

The effect produced by adding sulphuric acid to the cement in this way is due to the fact that a supho-aluminate of lime is formed, and the setting of the cement is arrested. The result is that when the setting does take place, it is due to the hardening of silicate of lime, which is well known to take place ordinarily some time after the phenomena of setting.

Thus we have the peculiar fact in regard to treated cements

that they set very slowly but harden very rapidly, showing strength at seven days neat from 25 per cent. to 60 per cent. greater than the untreated cements. This peculiar combination of properties seems to me a very valuable one for cement mortars subjected to fresh water exposures, but it is entirely clear from the tables submitted that the addition of sulphate can easily be overdone, and an amount added which will make the cement not only bad but dangerous. Hence I think that there is no matter of greater importance than the regulation of this use of sulphate.

TABLE VII.

(D) Effects of Sulphate—Another American Portland Cement Treated with Plaster of Paris.

	7 Day Neat.	7 Day 3 to 1.
As sampled	464 lbs.	167 lbs.
Plus $1\frac{1}{4}$ per cent. sulphate	655 "	219 "

A gain by addition of sulphate of 41 per cent. neat, and 31 per cent. 3 to 1.

TABLE VIII.

(E) Effects of Sulphate—An English Cement Treated with Plaster of Paris.

	7 Day Neat.	7 Day 3 to 1.
As sampled	502 lbs.	110 lbs.
Plus 1 per cent. sulphate	810 "	111 "
" 1.5 " "	758 "	128 "
" 2.0 " "	804 "	134 "
" 2.5 " "	692 "	115 "
" 3.0 " "	535 "	93 "

A gain by addition of sulphate 60 per cent. neat, and 22 per cent. 3 to 1.

TABLE IX.

(F) Effects of Sulphate—A Second English Cement Treated with Plaster of Paris.

	7 Day Neat.	7 Day 3 to 1.
As sampled	528 lbs.	156 lbs.
Plus $1\frac{3}{4}$ per cent. sulphate	787 "	211 "
	28 Day Neat.	28 Day 3 to 1.
As sampled	590 lbs.	199 lbs.

A gain by addition of sulphate at 7 days of 45 per cent. neat, and 35 per cent. 3 to 1.

TABLE X.

(G) Effects of Sulphate—A German Cement Treated with Plaster of Paris.

	7 Day Neat.	7 Day 3 to 1.
As sampled	579 lbs.	201 lbs.
Plus $1\frac{1}{2}$ per cent. sulphate	747 "	265 "

Gained by addition of sulphate 29 per cent. neat and 32 per cent. 3 to 1.

To further illustrate the effects of treating cements with sulphate of lime, tables VII, VIII, IX and X are given above. In table IX the effect of adding a small percentage of sulphate in seven-day tests can be compared with 28 days' tests of the cement as sampled. It will be seen that the small adulteration has made the cement mature in seven days considerably beyond what it otherwise would have done in 28 days.

TABLE XI.

WEIGHTS OF DRY SANDS.

	Per 100 C. C.	Per Bushel.
Standard	138 grammes.	92.0 lbs.
B	152 "	101.5 "
N	155 "	103.5 "
G	155 "	103.5 "
H	157 "	104.9 "

SPECIFIC GRAVITY AND VOIDS.

	Specific Gravity.	Weight of 100 C. C.	Voids.
Standard	2.63	138	47.5 per cent.
B	2 63	152	42.0 "
N	2.67	155	42.0 "
G	2.62	155	41.0 "
H	2.67	157	40.0 "

In table XI are given the weights, the specific gravity and the voids of standard sand in comparison with four natural river or bar sands. It will be seen that the natural sands when dry weigh a little over 100 pounds per bushel, and it is easy, therefore, to proportion mortars by weight, by adding to 100 pounds of cement one, two or three scant bushels of sand to produce mortars of 1 to 1, 1 to 2, or 1 to 3 mixtures as desired.

In regard to voids, it will be seen that they exceed 40 per cent. in all cases, and that, therefore, in a 1 to 3 mortar the cement is not in sufficient quantity to entirely fill the voids.

This leads me to suggest that in concretes it will be much better to use proportions of 1 cement, 2 sand and 5 or 6 stone, than 1 cement, 3 sand and 4 stone, as is often required. The voids in broken stone vary with the size and the uniformity of the stones,

but as used in concretes they are generally less than 40 per cent. of the volume of the stone.

TABLE XII.

7 Day Tests 3 to 1 of Cements with Different Sands.

Cement.	Sands.				
	Am. Std.	G. S.	H	N	B
G	196	163	194	201	123
S	219	190	190	213	119
C	194	147	148	148	106
A	200	198	180	186	77
Sh	219	233	299	255	113
P No. 3	194	174	189	171	87
As	191	183	213	239	115

In table XII are given comparative tests of natural sands with the American standard sand. Seven different cements were used in these tests and four natural sands, one of which, however, was a carefully sifted sand used as a standard in Germany. This one is marked G. S. The sand marked H is a bar sand used in this city, the one marked N is a red sand from the Niagara River, and the one marked B is the ordinary bar sand in use here.

As a result of tests of this kind, I am convinced that the only way to determine the value of sand for mortar purposes is to test it with the cement to be used. The Niagara River red sand N is a sand which nine persons out of ten would consider a poor mortar sand. It has a large percentage of fine material in it, and it also looks dirty and somewhat loamy, yet when tested with cements, it proves to be an excellent sand, one of the best of the series given in the table, averaging up very well with the American standard sand.

In discussing the specifications submitted I would say, referring to Article 1, that it seems to me quite impracticable to make definite requirements for the acceptance of cements beyond seven days' time. I do not dispute that it is important and desirable to prepare tests from the cements used for various periods up to several years' time, but it is manifestly impossible to make the

acceptance of the cement wait for the results of these longer time tests. On the other hand it is perfectly practicable and, I think, desirable to require parties who wish to sell cements to submit well-authenticated records of test results for periods up to at least one year, and also to submit samples of the cements which they are prepared to furnish.

Article 3 deals with fineness. The fineness of cements is a property which is valuable only in results. Its advantages accrue entirely to the manufacturer and not to the engineer. Unless the cement is finely ground, it would be impracticable to get good sand tests out of it; but, on the other hand, if the sand tests are satisfactory, it is a mistake for an engineer to haggle over a point or two in fineness. It must be remembered that the hard burnt black clinker, which is the best part of the cement, is much harder to reduce to a fine powder than the underburnt clinker which comes from the kiln. A demand for unusual fineness, therefore, may result in barring the best cements.

The history of fine grinding is simply this: In England, where the standard test is a neat cement briquette, the grinding is coarse; in Germany, where the sand briquette is the standard test, the grinding is much finer; in America, cement is generally very finely ground, simply because of the excellence of our machinery and mechanical pride of our engineers. But there is absolutely no evidence that the coarse grinding is, *per se*, in any way detrimental or injurious to the cement. In engineers' specifications for cements, therefore, there is no good reason apparent for pushing fineness to an extreme; it is desirable only to specify a good average standard, debarring those which cannot be expected to meet the sand test.

In this city we have had the 200 sieve introduced, and to my knowledge it was introduced by an agent for the purpose of limiting competition. Now there is no such thing as a standard 200 sieve, and if there were, it would be a nuisance to use it. The sieves of the American Society are accurately defined by giving both the mesh and size of wire, but the 200 sieve is nowhere defined, and therefore the sieve which one man uses may differ materially from that used by another. I can see no reason for continuing the use of the 200 sieve.

Article 4 deals with specific gravity. Formerly it was the custom to require certain volumes of cements to weigh certain amounts, but this has proven impracticable, because of differences in fineness. The finer the cement, the greater the bulk it occupies. The specific gravity test is very easily made and quickly made, and seems to me a desirable test. When freshly ground, cement clinker has a specific gravity exceeding 3.1; after seasoning and taking up moisture and carbonic acid from the air, the specific gravity falls below 3.1, but still should exceed 3.05. If a cement, however, is adulterated by the addition of slag, or of limestone rock, or by mixture with natural cements (all of which things have been done), the specific gravity falls considerably, because these adulterants all have specific gravities of about 2.6. So also if the cement contains too much free lime, it will by seasoning take up enough moisture and carbonic acid to reduce the specific gravity below 3.05 per cent.

I am inclined to think it would have been better to have fixed the gravity requirements at 3.05 per cent. as is done by the standard specifications of the *Ponts et Chaussées*, in France, but as it looked like a refinement I left it at an even 3.00.

In Article 5, we have the standard cold pat test which has been approved by the American Society of Civil Engineers, and is a standard also in England, France and Germany. The various accelerated tests which have been proposed have so far failed of adoption by any of the representative bodies in these countries. I have recently presented before the American Society of Civil Engineers a series of tests which convinced me that the boiling test is not satisfactory, so shall not stop to discuss that question here.

In discussing the chemical requirements of the draft of specifications, it may be said that there are three elements in cements which must be limited. These are, first, sulphuric acid, second magnesia, and third lime. It is hardly necessary to point out the disadvantage of a compound like sulphuric acid in cements. We know that the sulphates in sea waters are the prime elements in the destruction of Portland cements in salt water exposures. It is confidently stated also that Portland cements placed in water, containing a saturated solution of sulphate of

lime, will disintegrate. We have seen in the tables IV to X inclusive, submitted above, that an excess of sulphuric acid is immediately injurious to cements, and as treatment with sulphate of lime has been widely adopted it becomes important to regulate its amount. Magnesia hydrates to form a hard crystalline body, but it does so with an increase in volume. It is also sluggish in hydrating and its effects in cements are often seen long after the cement is hardened. Owing to the destructive elements in sea water it is particularly desirable to limit both the lime and magnesia for salt-water exposures. The presence of an excess of lime in cements is well known to cause their rapid disintegration by blowing, warping or in some cases by complete rotting.

Now the sulphuric acid and magnesia can both be determined by chemical analysis; but the excess of lime can not be determined chemically. The reason why the excess of lime can not be determined chemically is that practically the lime must always be below the theoretical limit. Thus approved formulas for cements indicate a proportion of lime to silica and alumina (by equivalents) of 3 to 1, but as a matter of fact it is found practically impossible to bring every particle of lime into such intimate contact with the particles of silica and alumina that a perfect chemical union can be formed. Hence the amount of lime present in cement is ordinarily about 80 per cent. of the theoretical amount required. Various methods have been proposed to determine the lime which is free from that which is in combination, but none of them have yet been found satisfactory, and we are compelled to rely upon cold pat tests to indicate the presence of free lime.

The French regulations specify that the ratio of the silica plus the alumina to the lime must be at least 44 per cent., and this might be a very good regulation to make for cements subjected to salt-water exposures.

One of the features suggested by the specifications is a division of cements into three classes. It is certainly necessary to divide them into two classes, but it may be questioned whether the third is necessary. We must recognize the difference between treated and untreated cements, and I thought it desirable, for purposes

of discussion at least, to emphasize the qualities required in cements for salt-water exposures. Hence have made this a third division.

The best of the treated cements, containing not more than 2 per cent. added sulphate of lime (equal to 1.18 per cent. of anhydrous sulphuric acid), seem to me to be admirable cements for fresh-water exposures. They have, as has been pointed out above, the property of setting slowly combined with a more rapid hardening, and this is admirable for mortar purposes. For salt-water exposures, however, treated cements will not do. They are debarred in France, where the sulphuric acid is limited by regulation to one per cent. They are not made at all in England, because all cement there must be made to stand salt water exposures, and in Germany a quick setting or untreated cement is made for salt-water work. Besides this, it has been agreed te regard the addition of any foreign matter to a normal cement as an adulteration, and there are manufacturers who are unwilling to adulterate cements in any way.

For these reasons it is necessary to separate the treated from the untreated cements, and as they exhibit marked differences in physical properties it becomes necessary to place different requirements upon them. Again, as pointed out above, it is important that this adulteration to cements should be carefully regulated, because an excess of sulphuric acid will immediately deteriorate the quality of a cement. I should think it desirable to keep the amount of sulphate well within the amount which seems to produce the maximum tensile strength at seven days. It is evidently easy to obtain high results from indifferent cements by pushing the adulteration to an extreme, and there is no doubt in my mind that foreign cements have been so sold in this country after treatment, which could not be sold in Europe, where tests and specifications are better looked after.

It appears that the distinction between treated and untreated cements is also not entirely novel. Mr. Max Gary (*Transactions Am. Soc. C. E.*, October, 1893, page 21) gives the following, quoting article 6th of the German regulations: "Quick setting cements generally show a lower strength at 28 days than that given above. The time of setting must therefore be given when stating figures relative to strength."

Under mortar I have required that the sand must be dry. This was put in, because I knew it would please everybody, as it is one of those things which everybody says should be done, and which nobody does. In my judgment, if the sand is simply damp, there is no objection to using it in this condition in mortars, and in fact with the quick setting cements it seems to have a positive advantage from the fact that it makes cement slow setting.

SPECIFICATIONS FOR PORTLAND CEMENTS AND FOR CEMENT MORTARS.

The following draft of specifications has been prepared by the author for the purpose of inviting discussion and for no other reason :

General.

1. *Records and Samples.*—Parties offering cements for Engineering Works must be prepared to file satisfactory records of tests both neat and in sand mortars for periods up to at least one year, and also records of analyses, showing proportions conforming to recognized standards, and to the chemical requirements below. Such tests and analyses must be made by competent parties, certified by them to be correct, and if required, sworn to.

Prior to the award of contracts, parties wishing to be considered will submit samples duly marked for identification, and each guaranteed to be an average sample of the cement to be furnished in the event of an award. The samples will be used for preliminary tests and also preserved for comparison with the cement delivered for use.

2. *Testing.*—The briquette moulds, sand, sieves, setting, needles, etc., and the methods of making briquettes and of testing will all be in accordance with the recommendations of the American Society of Civil Engineers, with this exception, viz. : that the cement may be screened through a No. 30 sieve if necessary, to remove lumps and foreign matter, but other than this, briquettes will be made up from cements as samples without sifting.

Tests for setting time, fineness and the 7-day tensile tests required below will be made from each sample taken. The chemical tests will be furnished by manufacturers before the award of contracts, but will be confirmed by occasional tests of the cement furnished. The requirements in tensile tests are for an average of a set of five briquettes in each case.

3. *Fineness.*—Cements will not be considered unless they are ground so finely that 97½ per cent. will pass through the standard No. 50 sieve, and 87½ per cent. through the No. 100 sieve.

4. *Specific Gravity.*—Cements will be required to have a specific gravity exceeding 3.00.

5. *Constancy of Volume.*—When made up neat in pats 3½ inches in diameter, ⅜ inch thick at the center, and drawn to a sharp edge at the circumference, the

cements must show no evidence of cracking, checking or warping when exposed in the air, or in water at normal temperature, for one week.

6. *Sampling, Storing and Accounting.*—All tests will be made from average samples selected at random from 10 per cent. of the packages offered. Not more than 150 barrels will be accepted on one set of tests, and no cement will be used which has not been duly sampled and tested at seven days.

Contractors will provide good and sufficient storage for cements, so that there shall always be an ample stock on hand, and will protect the stock against intrusion or the use of lots not authorized.

The inspector will have free access to the storehouse at all times, and will be afforded every facility for identifying and accounting for different lots of cement in store. He will be furnished promptly with duplicate invoices and bills of lading of all cement for the work as shipments are made.

In case of rejection, the lot of cement condemned must be removed from store within twenty-four hours.

7. *Cost of Testing.*—Parties making propositions for furnishing cements will include in their prices a sum sufficient to cover the cost of having the cement regularly sampled and tested in a manner satisfactory to the purchaser.

8. *Limits of Accuracy.*—Chemical determinations will be considered accurate to the nearest tenth of a per cent.; tensile tests to the nearest ten pounds. Within these limits tests must meet the requirements of specifications or the cement will be rejected. There will be no retests.

9. *Cements for Salt Water Exposures.*

Initial set with fresh water, not less than ten minutes.

CHEMICAL:

Sulphuric Acid (SO_3) less than	1.00 per cent.
Magnesia (MgO) less than	1.00 "

TENSILE TESTS:

1 day neat		Not more than 45 per cent. of tests at 7 days neat.
7 "		375 pounds.
7 "	3 parts sand to 1 cement	135 pounds.

10. *Quick Setting or Untreated Cements for Fresh Water Exposures.*

Initial set, with fresh water not less than ten minutes.

CHEMICAL:

Sulphuric Acid less than	1.25 per cent.
Magnesia less than	2.50 "

TENSILE TESTS:

1 day neat		Not more than 45 per cent. of tests at 7 days neat.
7 "		375 pounds.
7 "	3 parts sand to 1 cement	150 "

11. *Slow Setting or Treated Cements for Fresh Water Exposures.*

Initial set, not less than ten minutes.

CHEMICAL;

Sulphuric Acid less than	2.00 per cent.
Magnesia less than	2.50 "

TENSILE TESTS:

1 day	neat	Not more than 45 per cent. of tests at 7 days neat.	
7	"		475 pounds.
7	"	3 parts sand to 1 cement	175 "

MORTARS.

12. *Sand.*—The sand used shall be of such quality that it will give in laboratory tests 3 to 1 at 7 days 60 per cent. of the tensile strength required for briquettes made with standard sand, and briquettes made directly from the mortar box will similarly be expected to show 33 per cent. of the test requirements for standard sand.

In laboratory tests of sands, the lumps will be removed by sifting through a No. 20 sieve.

13. *Mixing Mortars.*—The sand must in all cases be dry, and will be stored in such a way that it can be kept dry. For mortars, sands will be sifted so as to exclude lumps or particles larger than $\frac{1}{8}$-inch diameter; for concrete to exclude those larger than $\frac{1}{4}$-inch diameter. In proportioning mortars the cemsnts will invariably be measured by weight, the sand by bulk to be agreed upon. A thorough mixture of sand and cement will be made dry, after which the water will be added by sprinkling and the whole mass worked to a temper.

The amount of mortar to be mixed at one time will be fixed to suit the character of the cements. No mortar will be used which has been mixed over night or over a length of time fixed by the inspector.

14. *Lime in Cement Mortars.*—In the case of a mixture of lime and cement in mortars, the lime must be slacked at least ten days before using.

15. *Concrete.*—In making concretes the cement and sand will first be mixed dry in the manner set forth above and worked both dry and wet to a temper. The stones measured by bulk will first be sprinkled and then added to the mortar and well worked in.

The concretes will be made with a minimum of water to admit of being rammed in place without showing an excess of surface water.

DISCUSSION.

MR. ROBERT W. LESLEY.—I have heard with great interest Mr. Lewis' very able exposition of how cement should be tested, and the advantages to be derived from such a specification as is submitted by him.

All that he says on this subject is of great interest, and is the result, as I know, of considerable experience in testing cements in a well-equipped laboratory. My own standpoint in considering this matter, while predicated upon the laboratory results, is also predicated upon the manufacturer's point of view, as well as that of the consumer. To make the tests suggested by Mr. Lewis would require what he very properly says is necessary—a thor-

oughly equipped mechanical and chemical testing laboratory. Such a laboratory, of course, would be impracticable in the average work done with cement throughout the country, and while the results that Mr. Lewis seeks to have adopted would be secured in such a laboratory as he has, they would not be secured in the ordinary testing laboratory on public work in this country. The question therefore to be considered in discussing such a specification as Mr. Lewis suggests, is, whether engineers or others would or would not strive under unfavorable conditions to require of manufacturers results which, under the ordinary method of treating cement on the work, would be unattainable. When it is considered that in the ordinary method of testing cement, embracing merely the elements of fineness, checking and tensile strain, so well-informed a writer as John Newman, whose book is a standard authority in England, names no less than ninety elements of error as likely to occur, is it not possible that to refine still further the refinements of refined testing is going a step too far in the direction of absolute safety? In my own experience in various testing laboratories, on work in this country, I have found innumerable possibilities of error under the ordinary standard method of cement testing suggested by the Am. Soc. C. E. For instance, in one case I found one briquette out of ten in a row check three days hand-running. After several days' watching, I found that this briquette was uncovered by the damp cloth which was only long enough to cover nine out of ten briquettes. Thus the tenth briquette was exposed to the rays of the early morning sun, which invariably caused it to check by sudden drying—the other briquettes being sheltered from this exposure. In another case I found that sand of an inferior quality was used in making briquettes. In another case a tester had been appointed who had never until the day of his first work tested cement. In still another case, I found that 40 per cent. of water was used in making the ordinary neat briquettes, thus drowning the briquette. In another case only 10 per cent. of water was used, thus giving an entirely insufficient quantity. In addition to this I found cases where the briquette moulds were filled with rust; where the moulds were not greased; where the briquettes were put upon wood and the water

allowed to soak out of them; where the briquettes were put upon a steam heater coil and the water allowed to be driven out—and so on, showing a hundred cases of possible error in the ordinary conditions of testing cement.

Taking up Mr. Lewis' specification and considering it therefore, *not as a method of testing cement upon work, but as a method of testing cement in the laboratory*, and considering, for the sake of argument, that laboratory tests under scientific auspices are to supersede tests under the ordinary method upon public work, let us see where we can agree with and where we can criticise what Mr. Lewis has laid before us to-night.

There can be no criticism from the standpoint above mentioned of the necessity and wisdom of parties bidding for engineering works, submitting records of analysis showing proportions conforming to recognized standards, and to the ordinary chemical requirements of a Portland cement, nor that these records should be properly certified and sworn to if necessary. No cement manufacturer of established reputation would care to submit a sample, or care to manufacture and deliver as Portland cement, an article not conforming to the recognized standards, nor should any manufacturer object to the comparison between the samples submitted with the bid and the subsequent barrels submitted in actual performance of the contract.

So far as the ordinary method of testing is concerned, that of the Am. Soc. C. E. is proper and right, and has stood the tests of time. Large works have been done with it, and excellent results achieved.

The screening of the sand and cement to remove lumps and foreign matter cannot be criticised, nor can the requirements as to the determining of the specific gravity of the cement.

The average of five briquettes is perfectly proper, especially where that average is made from all the briquettes broken. As instancing the varying opinion of engineers upon so simple a matter as this, it might be mentioned that on two large works where contracts have been lately let, only those briquettes have been considered which broke *exactly* at the inch section, and the argument was seriously advanced, that where a briquette broke *above* or *below* the actual inch section, that that was an unfair

break, and should be thrown out, inasmuch as it gave a higher test than the break of the inch section would have done. In this connection opinions were obtained from five leading engineers and five leading laboratories, and in each and every case the conclusion was given that if the inch section did not break it was indicative of the fact that the inch section was certainly stronger than that part of the briquette at which the break was made (or, in other words, sustaining the principle that the measure of the strength of a chain is the measure of the weakest link), and that therefore when the inch section has withstood the strain, certainly it is proof that the strain at which the briquette broke is the true measure of the breaking strength of the smaller inch section.

So much for the general elements of Mr. Lewis' suggested specification.

Coming now to the elements which enter into nearly all the specifications in all countries, it may be interesting to take up and see what is required of cement on large work all over the world, and about what results are arrived at on cements so tested. The writer had occasion, not long since, to go over this question very thoroughly, and took the trouble to gather from specifications, which he had accumulated for many years, the elements of fineness, tensile strain and checking of many specifications.

Fineness.—Upon the first head the following finenesses are required by the governments of Europe:—

Belgium..............................15 per cent. on a 5,800 mesh sieve (Genie Belge).
Germany .... 10 " " 5,800 " (Rules Prussian).
Switzerland ....15 " " 5,800 " (Report Tetmajer, Zurich).
France................................No fineness specification (Cahier des charges, Ponts et Chaussées).
France............................. 5 per cent. on a 5,800 mesh sieve (recommended by Le Chatelier and Candlot, French chemists).
Roumania............................12 per cent. on a 5,800 mesh sieve (Government specification).
England .... 8 per cent. on a 2,500 mesh sieve (recommended by H. Faija, World's Fair Congress, August 2, 1893.)
United States.........................Recommendation American Society of Civil Engineers, June 27, 1893, says: "Cements of better grades are ground so fine that only from 5 per cent. to 10 per cent. is rejected on a sieve of 2,500 meshes per square inch."

Under this recommendation are the following specifications in this country: —

New York Aqueduct	80	per cent.	on a	10,000	mesh sieve.
City of Baltimore	90	"	"	3,000	"
Department Public Works, New York	90	"	"	2,500	"
Pennsylvania Railroad	90	"	"	2,500	"
U. S. Government, District of Columbia	95	"	"	2,500	"
" " " " "	85	"	"	10,000	"
U. S. Government, Supervising Architect	no fineness specified.				
Niagara Falls Tunnel	80	per cent.	on a	10,000	mesh sieve.
Reading Terminal	95	"	"	2,500	"
U. S. Government, Board of Engineers	95	"	"	2,500	"

Tensile Strength.—In this test there are two elements, first, the neat cement test, and second, the test with sand. Below will be found a summary of requirements and tests under the branch of testing. In the case of European specifications, kilogrammes and centimeters having been roughly reduced to pounds and inches.

	Neat tests, 7 days.	28 days.
France	284 pounds.	497 pounds (Cahier Gullian).
Russia	255 "	(Russian Public Work).
Belgium	255 "	497 pounds (Genie Belge).
England	350 "	(Faija).
Germany	no neat requirements.	

American Society of C. E., 250 to 550 pounds, 350 to 700 pounds (tests recommended).

Under these recommendations are the following American specifications:—

	7 days.	28 days.
U. S. Government, Lighthouse Engineers	400 pounds.	
U. S. Government, Army Engineers	400 "	
U. S. Government, Supervising Architect	300 "	
U. S. Government, District of Columbia	400 "	500 pounds.
City of Philadelphia	300 "	
City of New York	300 "	
City of Baltimore	400 "	
New York Aqueduct	300 "	400 pounds.
Niagara Falls Tunnel	300 "	400 "
Pennsylvania Railroad Co.	303 "	412 "
New York Central Railroad	300 "	500 "
Reading Terminal	350 "	
Baltimore & Ohio	300 "	
Lehigh Valley Railroad	300 "	
New York City, Third Avenue Bridge	300 "	500 pounds.
Metropolitan Railroad, New York	300 "	
East River Bridge, New York	303 "	

SAND TESTS—3 SAND TO 1 CEMENT.

	7 days.	28 days.
France		215 pounds.
Germany		227 ‘
Russia		142 “
Belgium		215
England		none.
American Society of C. E. recommends	80 to 125 pounds.	120 to 200 pounds.

Under these recommendations are the following specifications:

	7 days.	28 days.
U. S. Government, Lighthouse Engineers	100 pounds.	
U. S. Government, Army Engineers	125 “	
U. S. Government, District of Columbia		150 pounds.
U. S. Government, Supervising Architect	none.	
Niagara Falls Tunnel	90 pounds.	
New York Aqueduct	100 “	
City of Baltimore		150 pounds.

From the above figures it will be seen that for non-treated cements the *neat* 7-day test of 375 pounds suggested by Mr. Lewis is a little high. This is susceptible of proof. For one instance under this element of tensile strain, showing that cements with moderate strain at 7-days neat, give excellent results at long periods, the following table from W. McCulloh's printed paper on the Sodom dam of the New York Aqueduct, *Transactions Am. Soc. C. E.*, Vol. 28, March, 1893, gives an illustration of what can be obtained—the cement in question being American Portland cement—the Giant Portland Cement, manufactured by the American Cement Company, Egypt, Lehigh Co., Pa.

	1 day. Av. lbs.	1 week. Av. lbs.	1 mo. Av. lbs.	3 mos. Av. lbs.	6 mos. Av. lbs.	9 mos. Av. lbs.	1 yr. Av. lbs.
Neat	140	348	422	540	634	638	682
2 to 1		166	280	364	460	468	490
3 to 1		140	234	350	368	428	420

	15 mos. Av. lbs.	18 mos. Av. lbs.	2 yrs. Av. lbs.	30 mos. Av. lbs.	3 yrs Av. lbs.	4 yrs. Av. lbs.
Neat	687	672	694	704	736	771
2 to 1	526	530	564	668	680	674
3 to 1	500	514	512	516	572	

A similar result carried out to a period of a year, is shown in a paper on the Niagara Falls Tunnel, published in *Engineering Record*, Aug. 19, 1893, where the same cement was used, and where the figures, as stated, were carried out to the period of a

year. On two other dams of the New York aqueduct, where figures have not yet been published, the record of tests runs up nearly to the same figures as those given on the Sodom dam, though the time period has not been carried to the same length, the work being more recent. Messrs. Wilson Bros. & Co. also used American Portland cement of moderate tensile strain at 7 days, on the Reading Terminal and Drexel Building, Philadelphia, and got results at long time periods, neat and sand mixtures closely approaching those above given. So much for the proof that cements giving about 300 to 350 neat at 7 days give excellent results at long periods, and in the writer's opinion a raising of the requirments at 7 day neat seems inadvisable.

CHECKING.—The general concensus of opinion all over the world is about as follows on the subject of accelerated or boiling tests:

Germany—After three years' discussion, the boiling test was finally reported against at the session of 1893, by the German Cement Association, operating in conjunction with the Prussian Minister (Gary's paper, World's Fair Congress, Aug., 1893).

French Government—Conference of Engineers Ponts et Chaussées, Cahier Guillain, Service de la Marine, Service de Colonie. None of these contain boiling tests.

England—Faija's paper, World's Fair Congress, Aug. 2, 1893, recommends steaming test only, and immersion at 116 degrees F.

Am. Soc. C. E.—Proceedings June 20, 1885, requires no boiling test.

From this compilation of tables and requirements from specifications, it may be briefly stated that on the first of these three elements of the ordinary testing of cement, Mr. Lewis' requirements are possibly a little too high on the residue on a 100 mesh sieve. He is entirely right in his exclusion of the 200 mesh sieve; any sieve holding 40,000 holes to the square inch, requires too much time to count in these busy days of ours when life indeed is too short. On the No. 50 sieve, Mr. Lewis is very nearly right in raising the requirements from 90 per cent. to 97 per cent., as most of the well-ground cements that will give residues of less than 20 per cent. on a No. 100 sieve, will give less than 3 per cent. on a No. 50 sieve.

So far as the tensile strain is concerned, as relating to cement untreated, the writer is of opinion that under the figures above given, the neat test is too high, for the reason that in order to get the 3 to 1 sand test of 150 pounds, it is necessary to grind the cement so fine as to make it low pulling in 7 days neat. These remarks of course apply to the ordinary tests made in the ordinary laboratories, though it is admitted that under the most favorable circumstances in the best organized and scientifically equipped laboratories, such results as Mr. Lewis' specification requires, may be obtained. That a 300 to 350 pounds specification at 7 days neat will give good results, the writer thinks is amply substantiated by the figures above given, and this is corroborated by a paper read a number of years ago before the Institute of Civil Engineers, London, by Mr. Reginald Empson (*Eng. News*) where taking a series of cement tests that had broken at figures between 300 and 350, 350 and 400, 400 and 450, and between 450 and 500 pounds at 7 days neat, he found that those in the first two classes showed a gain at periods of a year and over, while those in the last three classes showed in the first case a slight falling off, while in the other two cases a marked falling off at periods of a year and over was shown.

Now in this connection, therefore, considering this table of Mr. Empson, and considering the remarkable records above given with reference to low pulling, 7 day neat cements, we come to the question of the wisdom of using treated cements as referred to in Mr. Lewis' paper. We do know that the untreated cements, such as are mentioned in the records above given, do give at long time excellent results, but so far as the writer's knowledge is concerned, there is no long time record at periods over a year, with cements that have been treated with sulphate of lime in the form of gypsum or in the form of calcined plaster. There is, however, in the record of Mr. Empson, the fact that cements which he experimented with and which did give the results of sulphate of lime cement at 7 days neat, did go back at long periods, presumably from this cause. Consequently while the distinction that Mr. Lewis makes between treated and untreated cement is perfectly proper, inasmuch as the treating of

the cement with calcined plaster in a small percentage will largely increase its tensile strength at 7 days, the writer questions whether such a cement will in time prove absolutely sound, and therefore, though there is this distinction made in Mr. Lewis' tests, and one which is fair to the untreated cements, the writer still has doubt as to the availability of cements thus treated. It is a well-known fact that for salt-water work, a cement containing sulphate of lime is considered by Candlot and Feret, after a series of experiments, absolutely unsuitable. Large works, such as some of the bridges in New York Harbor, have excluded cements containing sulphate of lime in the form of gypsum or calcined plaster as an adulterant, and certainly the manufacturers of this country on the sea-board should consider very seriously the wisdom of engaging in a practice whereby they would be compelled to require of their customers on the sea-board, a guarantee that all the cement thus adulterated with sulphate of lime would not be used for salt-water work. It can readily be seen that a failure resulting for such use would be a serious blow to the American cement manufacturer of all kinds of Portland cement. In England, where most of Portland cements are used for salt-water work, it can be laid down as a general fact that this form of adulteration is not engaged in.

Boiling Test.—On this point, the writer can agree entirely with Mr. Lewis, and that is upon his tests for constancy of volume. He says that the boiling tests are not used and the normal tests of the German Society is the one adopted. There can be no criticism in what Mr. Lewis has to say of sampling, storing and accounting, nor upon the manufacturer paying the cost of testing, where the testing is to be done in a well-equipped scientifically managed laboratory. The same remarks will apply to the limits of accuracy mentioned by Mr. Lewis.

The one other thing that I think all cement manufacturers will agree in, and that is that Mr. Lewis' specification bears at least the marks of consistency. The writer had occasion, about a year ago, to be asked to bid upon a specification which was inconsistent in all its particulars. Its framer had evidently read much and considered much, and had taken the various parts

of his specification from books and other specifications which were no doubt before him. What was written, was interesting in each and all its particulars,—as a whole it read like a romance,—as a practical specification it was impossible for any manufacturer to bid on it, without, in the words of Heath, London, 1883, giving an "untrustworthy cement that will probably become weaker and then disintegrate with age." This one case illustrates some of the difficulties that are to be met with in specification making, and also illustrates the difficulty the manufacturer has in endeavoring to do a "split act" by meeting varying inconsistent elements of what might possibly be called a well-worded specification.

Mr. George S. Webster.—In considering the question of tests of cement from a consumer's standpoint, it is desirable to adopt those methods which will secure the best material for the purpose it is to be used.

In the works of construction being carried on by the City of Philadelphia, we have found it of great advantage to make sand tests of cement mortar taken directly from the mixing boxes on the work. By this means we can determine the results a cement will give under the treatment which it must receive on the work, which is more reliable than the simple laboratory test, for, in the former, we get results from the cement as it is actually prepared for use, and with a little care uniformity of mixing may be obtained.

In has been the rule in the City Departments of Philadelphia not to accept any new brand of cement until an opportunity was had to obtain the 28-day sand and neat tests, thus being able to determine in a very satisfactory way the quality of the brand. After this quality is established, the cement is accepted upon the 24-hours and 7-days test by the comparison of former tests.

It is also the custom to continue the testing of all brands of cement in use over periods of three, six, nine, twelve, twenty-four, thirty-six, and forty-eight months.

During the past year, Mr. Richard L. Humphrey, the Inspector of Cements, Bureau of Surveys, has moulded nearly 10,000 briquettes and broken 8,500.

This testing has included cement taken from shipments on all

sewer and bridge work, and also on numerous paving contracts where the base has been made of concrete.

A quick method for making "checking" tests is desirable.

Mr. Lesley.—The testing of cement from the mortar-board is a most excellent manner of determining practically the character of the cement in the work and has much to recommend it. It has been done on the New York Aqueduct for a number of years. Each inspector is provided with a set of briquette moulds and is supposed to test the cement from the mortar-box over which he has charge. The inspectors endeavor to get the best results from the mortar-boxes as well as in their briquettes, and in many cases the mortar-box tests closely follow the laboratory tests of the same cement. This applies to periods of three months and under. When the tests run up to periods of six months and over, the mortar-board figures have been known in many cases to exceed those of the testing room. Of course this would depend largely upon the character of the sand used on the work and used in the testing room. In the case mentioned the sand used on the work was of most excellent character, and very nearly equal to the standard sand with which the laboratory tests were made.

Mr. Richard L. Humphrey.—In establishing a set of specifications for cement one should be governed by the results of his *own* experience. The personal equation of the inspector plays such an important part in testing cements, that the results of the tests of different inspectors are valueless for purposes of comparison. Where large quantities of cement are used in construction the inspection and testing should engage the entire attention of one person. Upon the results thus obtained should be based the specifications for regulating the quality of the cement to be used.

Having established such a set of specifications it is immaterial what results other inspectors obtain from a cement, as one has fixed the requirements in accordance with his own method of testing.

It is a great deal better to place the requirements low and gradually increase them as it is found by experience to be necessary, than to place them too high and be compelled to lower them.

The sample for testing should not be one submitted by the

manufacturer, but one taken from an actual shipment on the work, nor should the certificates and testimonials furnished by cement manufacturers be considered in accepting or rejecting a brand of cement. It should be accepted or rejected on its own merits, as it is important to know what a cement *will* do, not what it *has* done.

In the matter of fineness I believe that a fine ground Portland cement should never leave a residue of more than one per cent. on a No. 100 sieve, and there should also be a requirement for fineness on the No. 200 sieve.

The finer a cement is the more sand it will carry. The coarse particles in cement are inert and have no setting qualities, although when pulverized make the best cement.

Mr. Lewis also appears to advocate the "cold water" test. I regard this test as practically valueless for detecting unsoundness for intervals of less than seven days. Max Gary, in his paper before the American Society of Civil Engineers, says that one objection to the "cold water" test is the length of time requisite, observations extending over twenty-eight days satisfy the requirements. Now it is not practical to hold a cement for twenty-eight day test, neither is it safe to permit its use without testing its unsoundness. If you permit its use and find afterwards that it is unsafe, it is not fair to the contractor to compel him to tear the work out. It is necessary therefore to have some quick method for detecting unsoundness.

Professor Spaulding, of Cornell University, has shown that pats of cements which showed no signs of disintegration until after six months or one year, gave positive evidence of disintegration in twenty-four hours, by means of the "hot water" test, and in every case where a cement proved to be unsound, the "hot water" test indicated it in from twenty-four to forty-eight hours.

In my opinion the "hot water" test is much more effective than the "cold water" test.

Whatever may be the cause of unsoundness in cement, whether it be "free lime," improper burning, magnesia or sulphuric acid, the engineer is pursuing a safe policy by adopting a test of which he is certain that the cements which pass it are sound.

The "hot water" test has not had a fair trial in this country,

and what little experimenting has been done, has not been extensive enough to warrant any positive deductions. Until there is positive proof that it is valueless, I think the engineer is justified in adopting it.

There is also a prevalent belief that sulphuric acid and magnesia are dangerous elements in cement, yet the information on this subject is so unreliable that there has been but little effort made to regulate their proportion in cement.

The St. Louis Water Works Department were among the first in this country to take up this subject, and their specifiations reject a cement which contains more than four per cent. of magnesia or more than three per cent. of sulphuric acid. To require only one per cent. or even two per cent. is to my mind a very severe test, and it is a question whether the manufacturers would furnish cement to meet this requirement, or if they did, whether they would raise the price sufficiently to cover the extra expense of manufacturing such a cement, and then there is a reasonable doubt as to whether a cement with only one per cent. of magnesia is any better than one with four per cent.

Max Gary says there is a special commission in Germany engaged in further detailed investigations, it is, however, certain that a cement may contain as high as five per cent. of magnesia without causing apprehension as to its qualities.

Until there is definite information on this subject, I do not think it is policy to require so severe a test as Mr. Lewis recommends.

The tabulated tests which Mr. Lewis has just shown, and from which he seems to have drawn his inferences, do not go beyond the seven day test. It seems to me that deductions obtained from such limited experiments are not fair ones, and had they been extended to a year or over, the results would have been more reliable and probably very different.

It is a mistake to pay so much attention to the results of the twenty-four hour and seven day tests. Slow setting cements usually attain their strength at the end of a long time, and by placing the twenty-four hour and seven day tests too high you will debar the best cements. It is better to place the twenty-four hour test low, the seven day test moderately high, and have a high twenty-eight day requirement.

The twenty-eight day test is the most reliable, and I was surprised that it was not included in Mr. Lewis' specifications.

A cement which shows by long-time tests a steady increase in strength is much more preferable for general use, than one which reaches a maximum quickly and then shows practically no further increase, and often loses its strength. Besides, these cements as a rule do not reach the ultimate strength attained by the slower setting ones.

Again I cannot see the force of distinguishing between treated and untreated cements. An engineer's object is or should be to secure the very best cement suitable for general use; where local conditions require an especially prepared cement, it should be the subject of special tests. If by treating cements their quality is improved, then we should modify our specifications, so as to permit their use; if, on the contrary, treating cements injures their qualities, then the specifications should be so modified as to exclude such cements. Specifications should not admit of two or three grades of cement.

The most important tests that can be made and from which the most reliable information can be obtained, is from the briquettes made from the mortar just as it goes in the work. It is then tested as it is actually used, and after it has passed the imperfect manipulation of the cement mixer. Too much attention is paid to the laboratory tests and too little to the mortar-box tests.

I believe that preference should always be given to a cement which shows the highest mortar-box tests at the end of a long period.

Our efforts should be directed to securing cements of the highest quality suitable for general conditions, and our specifications should be modified as our *own* experience justifies us. The specifications of other engineers are interesting to read, but should never be followed until proved by our own experience. Each engineer should make his own specifications adapted to the methods of testing peculiar to himself.

Mr. Robert A. Cummings.—I wish to remind the members that, in the *Bulletin de la Société d'Encouragement pour l'Industrie Nationale*, 1890, the eminent French engineer, M. H. Le Chatelier, says: "There is at present only one way of determining whether

the judgment passed on a cement by any system of testing is sound, and that consists in waiting half a century to see how the work stands."

There exists a great necessity for rapid test methods which will accurately indicate the ultimate conduct of the cement. I think that in the usual specification too much preference appears to be given to the tensile tests at the sacrifice of other qualities, and that cement should have a chemical composition specified, from which physical results of neat tests would vary but slightly.

It is impracticable to keep the limit of accuracy in tensile tests to ten pounds, as the personal equation would vary 25 per cent. I consider neat tests as the most reliable indication of the quality of the cement, and look upon the combined sand and cement tests rather as testing the usefulness of the sand than of the cement, except where a pure siliceous uniform-sized grain sand is used.

I believe cement tests with the "clean sharp" sands of different localities vary as the number of tests and are most unsatisfactory. Being impressed with this view, I made a few tests over two years ago, which not only substantiated the above hypothesis, but gave some interesting results. The bearing of different sizes of sand grains and composition of the sand was found to be fully as important as the various qualities of the cement. These experiments were so few in number that they could not be relied upon; they, however, indicated an advantage of 50 to 100 per cent. in strength for washed sand from the limestone quarries and ballast crushers over the washed quartz sand for the same size sand grains; also considerable increase in strength for coarse sand stopped on a No. 20 sieve, which was found the most favorable size grain for strength.

These results have been recently confirmed in elaborate and interesting tests at the Hamilton Graving Dock, Malta, by Messrs. Colson and Colson (*Proceedings Inst. C. E.*, Vol. XCV, Part I) and I give an abstract of them as being more extensive, hence more conclusive, than my own.

"The experiments with Portland cement of different makers were carried out by three methods,—(1) by 'hand'; (2) by 'machine' (vibrating), and (3) by a 'screw-press,' as follows:—

The cement was put dry into the mould, standing in a shallow tray, and pressed down by a plunger the exact area of a briquette, the sides of the mould were made high to serve as guides; sufficient water was then put into the tray to saturate the cement and leave about 1 inch remaining, care being taken that no water fell on the top of the cement, but was all taken up by capillary attraction. After twenty-four hours the briquette was removed from the mould, and immersed in water until required for testing. The difference between 'hand' and 'machine,' when neat cement was used, was small, the average of eighty-eight seven-day tests giving 365.67 for 'hand' and 362.74 for 'machine.' When, however, 2 parts of No. 16 to No. 25 sand and 1 part of cement were mixed and tested at forty-two days the 'machine' showed a considerable advantage, namely 165.69 for 'machine,' 145.84 for 'hand,' and 122.62 for 'press.' The grains of sand appear therefore to be more efficiently covered with cements by the action of the machine than by hand mixing.

TABLE I.

Comparative Strength of Mortars Made of Different Kinds of Sand Mixed in the Proportion of 2 of Sand to 1 of Cement. Same Cement Used Throughout. Tested at Three Months.

No. of Experiments for Each Result.	Sand Used.	Size of Grains of Sand.				
		Passed Through 64 Meshes per sq. in.	Through 64 Meshes. Stopped on 256 Meshes per sq. in.	Through 256 Meshes. Stopped on 625 Meshes per sq. in.	Through 625 Meshes. Stopped on 2500 Meshes per sq. in.	Through 2500 Meshes per sq. in.
		Average breaking strain in pounds per square inch.				
36	Silicious sand with a slight amount of calcareous sand .	146.00	171.95	169.71	146.15	131.39
36	Calcareous sand of siftings of limestone from stone breaker, etc. . . .	267.63	272.71	240 56	218.98	218.26
24	Sand of equal parts of each of the above, mixed . .	202.38	205.81	197.75	180.06	176.19

TABLE V.

Relation Between the Strength of Mortar, the Coarseness of the Sand and the Fineness of the Cement. Mortar Mixed as 2 of Sand to 1 of Cement. Tested at Forty-two Days. Cement Measured by Volume.

Number of Experiments for Each Result.	Size of the Grains of Sand.		Fineness of Cement as Tested.			
	Screened Through.	Stopped on	As Received.	Screened Through 2,500 Meshes per sq. in.	Through 3,600 Meshes. per sq. in.	Through 5,800 Meshes. per sq. in.
	Meshes per sq. inch.		Lbs.	Lbs.	Lbs.	Lbs.
12	64	. . . . .	172.77	195.36	211.10	214.11
6	64	2,500	120.36	144.81	150.46	153.92
12	2,500	. . . . .	120.54	135.55	148 05	136.66

TABLE VI.

Relation of the Fineness of Cement to the Strength of Mortar.

Size of Sand.	Fineness of Cement Used.			
	As Received.	Through 2,500 Meshes per sq. in.	Through 3,600 Meshes per sq. in.	Through 5,800 Meshes per sq. in.
Screened through 2,500 meshes	Lbs.	Lbs.	Lbs.	Lbs.
Per square inch	122.22	133.70	203.25	240.36

Each result is the average of six experiments. Same weight of cement used in all the experiments.

TABLE VII.

Relation of the Strength of Mortars Made with Silicious Sand (so-called) to the Amount of Calcareous Sand Contained in them. Mixed by "Hand" as 3 of Sand to 1 of Cement. Tested at Twenty-eight Days.

Size of Sand.	Percentage of Calcareous Sand in the Sample.			
	Nil.	2 per cent.	4.22 per cent.	8.45 per cent.
Screened through 256 meshes and stopped on 625 meshes per square inch	Lbs. 93.55	Lbs. 103.18	Lbs. 117.77	Lbs. 120.96

Each result is the average of six experiments.

"The silicious sand used was carefully prepared by soaking in sulphuric acid and water to remove all the lime possible, and then thoroughly washed to remove all traces of acid. It was then mixed with a known proportion of calcareous sand of the same gauge of grains before adding the cement. The increase in strength as the calcareous sand was added is clearly marked, and tends to show the great care that would be required in selecting standard sands for testing Portland cement to ascertain that the amount of lime was the same in each sample."

Probably the study by microscopic examination would throw some much desired light on the conduct of cements.

Mr. F. H. Lewis.—I am not prepared to agree with Mr. Lesley that 300 pounds tensile strength at 7-days neat for untreated cements is all that should be required.

Undoubtedly, with poor facilities and unskillful operators, such figures are quite high enough, but then the results obtained under such conditions are so erratic, that it is impossible to draw any conclusions from them, or to attempt to regulate work which is essentially irregular. The untreated cements of good quality, when in prime condition for marketing, not unfrequently show results as high as 500 pounds at 7-days neat, and very often exceed 400 pounds. Hence I think figures below 375 pounds do not represent a first-rate grade of Portland cement. Either quality or condition is somewhat at fault; they are, perhaps, too largely composed of underburnt clinker, or they are not seasoned.

The 7-day sand test for untreated cements is perhaps open to criticism; certainly, it is higher than usual, and I think rather higher than my tables justify.

Mr. Lesley objects to the use of untreated cements altogether, and would debar them on the ground that they are undesirable for salt water exposures. Unquestionably, they often are wholly unfit for salt water work, and it was for the purpose of emphasizing the qualities required in salt water exposures that I made a special class for such cements. I think, engineers in this country have not sufficiently considered the effects produced by the large quantities of chlorides and sulphates held in solution by sea water. But, to debar treated cements, I cannot agree at all. In the first place, it is quite practicable to produce commercially

treated cements containing less than 1 per cent. of sulphuric acid and fit for salt water work; and, in the second place, for fresh water use a properly treated cement, containing less than 2 per cent. of added sulphate, is, I believe, better than an untreated cement. Hence, it is only necessary to recognize this difference, and to specify accordingly to get entirely satisfactory cements for either purpose. It is true, the people who do not know and who do not specify may get into trouble, but they are sure to do this anyhow.

A review of Mr. Humphrey's remarks is not flattering to my present effort, because it appears that he has neglected to do me the honor of reading the advance sheets, or to consider what I have said on the floor. In this he is, perhaps, consistent, holding, as he does, that one's own experience should be all sufficient. But such a broad denial of the wisdom which is reached through conference, cannot possibly be granted by this Club, and I think it hardly fair therefore, to be asked to explain, that I have not suggested accepting cements on samples furnished by manufacturers; do not hold long time test records undesirable; and have prepared the entire specifications expressly for purposes of discussion. Neither is it clear, why the reasons for distinguishing treated from untreated cements should be again set forth.

Long time tests are valuable for purposes of information, but are not tests suitable for the reception of materials. In this country, 28-day tests are impossible as regular tests for the reception of cements; if they are specified, it becomes necessary to accept shipments on previous records. On this point, Mr. Humphrey, with singular inconsistency, argues for 28-day tests in briquettes, but urges the impracticability of such tests in advocating the boiling test.

In *Proceedings American Society Civil Engineers*, Vol. XXXII page 321, will be found set forth reasons why I do not think it advantageous to use the boiling test in accepting or condemning cements. After an experience with the boiling apparatus which few in this country can equal, I have felt dissatisfied with it. In the present state of our information we can experiment with it, but can not rely on it as an indication of quality. To urge its adoption, as Mr. Humphrey does, "until there is positive proof it is valueless," seems to me bad engineering logic.

In regard to the percentages of sulphuric acid, there need be no doubt that the figures specified can readily be met; the records available on this point are abundant. Untreated cements made with ordinary care contain from 0.3 per cent. to 1.3 per cent. of sulphuric acid, (SO_3), and this can readily be kept below 1.0 per cent. by excluding dust and ashes from the clinker. The bulk of the sulphuric acid is found in the ash, where it sometimes occurs as high as 8 per cent. In treated cements the sulphuric acid (SO_3) is generally below 2.0 per cent., never need be higher, and I confidently believe never should be. I question if the St. Louis specifications allow 3.0 per cent. of sulphuric anhydride (which is sulphuric acid as given in this paper). Such an amount would be equivalent to nearly 5.5 per cent. of sulphate of lime, which is certainly a dangerous amount in almost all cases.

It is surprising to find that Mr. Humphrey speaks of slow setting cements as attaining their strength "at the end of a long time." All the evidence seems to be conclusively to the contrary, that with a slow set there is rapid hardening. The difference in this respect is at least 25 per cent. in favor of slow setting cements in 7-day tests.

To take the position that there can be no standard in cement testing, except individual results, is to turn one's back on progress. As a result of the great body of work which has been done, and is still being done, for standard methods and better knowledge of cements by engineering bodies the world over, the progress toward comparable results in laboratory tests has been notable and continuous. To discard all this in favor of the individual methods and erratic results of the old practice is most unfortunate.

XXI.

BOILER EXPLOSIONS.

By John L. Gill, Jr., Member of the Club.

Read, December 15, 1894.

Much has been written upon this subject and considerable time and money have been expended in experimenting to determine, if possible, the cause of boiler explosions, and many theories have been advanced upon the subject. It is now well understood that disastrous explosions are produced by converting the stored energy contained in the steam and water of a steam boiler into active energy. This is occasioned by the sudden reduction in the pressure of the steam contained in the boiler, and usually takes place after a rupture in some of its weakest parts; then, as soon as the opening is made large enough, the heat stored up in the water causes all or nearly all of the water to be instantaneously expanded into steam and produces an explosive force that no ordinary boiler can resist.

It is possible and very probable that explosions of boilers may be compound; that is, part of the stored energy may be converted into active energy at one time, then another part at another time, and so on, and while the time between the explosions would be immeasurably small, still there would be separate explosions.

I present herewith a table that I have prepared from paragraphs taken from Dr. R. H. Thurston's work "Steam Boiler Explosions," which shows the amount of energy stored in different types of boilers and the disastrous effects possible by the sudden liberation of this great amount of stored energy.

In speaking of Sectional or Water Tube Steam Boilers, Dr. Thurston says: "The stored available energy is less in this class of boilers than of any other stationary boilers and not very far from the amount stored pound for pound by the plain tubular, the best of the oldest form."

"It is evident that their admitted safety from destructive explosions does not come from this relation, however, but from the division of the contents into small portions, and especially from

TABLE SHOWING THE AMOUNT OF STORED ENERGY CONTAINED IN VARIOUS TYPES OF STEAM BOILERS AND THE FORCE FOR POSSIBLE DESTRUCTION IN CASE OF AN EXPLOSION.

Abstract from Paragraphs in "Boiler Explosions." By R. H. Thurston.	Horse-Power.	Diameter in Inches.	Length in Feet.	Number of Tubes.	Size of Tubes in Inches.	Weight of Boiler.	Weight of Water.	Steam Pressure Carried in Pounds.	Stored Energy in Foot-Pounds.	Distance to which the Boiler may be thrown by the Stored Energy.	Initial Velocity. Feet per Second.
1. Plain Cylinder	10	30	30	0	0	1 tons	2 tons	100	47,000,000	4 miles	1,100
2. Cornish Boiler	60	72	36	1	36	7½ "	12 "	30	60,000,000	3-5 mile	470
3. Two Flue or Lancashire . . .	35	42	28	2	14	3 "	3 "	150	83,000,000	2½ miles	900
4. Return Tubular	60	60	15	66	3	½ ton	½ ton	75	51,000,000	1 mile	600

5. The Vertical Cylinder is of the same class as the Plain Cylinder.

6. The Vertical Tubular is of the same class as the Return Tubular.

those details of construction which make tolerably certain that any rupture shall be local."

It will appear from the above that a disastrous explosion of a well-designed Water Tube Steam Boiler is most improbable.

I quote from the same work :

" Comparing the energy of water and steam in the steam boiler with that of gunpowder as used in ordnance, it has been found that at high pressures the former become possible rivals of the latter. The energy of gunpowder is somewhat variable, but it has been seen that a cubic foot of heated water, under a pressure of sixty or seventy pounds per square inch, has about the same energy as one pound of gunpowder."

With such facts before us, the question may be asked, why are boiler explosions not more numerous? and why are they not more disastrous when they do occur?

The direct cause of boiler explosions may be due to one or more of the following primary causes:

(1) *Faulty design.* Where the proper care has not been taken to provide against excessive strains brought about by the unequal expansion and contraction of its parts, which cause cracks in the plates, leaking joints and leaks at the rivets loosen the tubes in tubular boilers.

In spacing the rivets too closely, so that the plates are weakened by cutting away too much of the material, using plates that are too light, using rivets that are too large, etc.

(2) *Bad engineering* is frequently displayed in the erection of boiler plants.

(3) *Poor material* is a great cause for weakness in boilers, and for this there is no excuse at the present time, as good material can be obtained without difficulty. The best is not too good.

(4) *Bad workmanship* is the most inexcusable cause of weakness, and yet it is of very common occurrence. Burning of the plates while being heated for flanging; cracking of the plates while flanging; cracking the plates while in the rolls for forming into shape, by sledging them with heavy sledge hammers; punching the holes so that many of the holes overlap each other; then by drifting and distorting the plates, so as to make it possible to enter the rivets, and then by driving the rivets in the bad holes;

burning of the rivets while heating them; driving rivets in the laps of plates that have not been brought into close contact with each other, whence it becomes necessary to rely upon the caulking to prevent leaks.

There are many other ways in which bad work is done in boiler shops. All of this bad workmanship can be avoided by employing intelligent and honest foremen for the management of boiler shops.

(5) *Wasting away* of the plates by corrosion, grooving and pitting; rusting while not in service; corrosion of boilers while in use, which have leaking joints and leaks at the rivets, especially when the leaks are near parts where ashes accumulate upon them (for most ashes contain sulphur, and when they are moistened by the steam or water from the boiler sulphuric acid may be formed, which causes very active destruction of the plates); corrosion of the plates in leaking boilers, where water is used from artesian or driven wells which contain salt, or using water from coal pits containing sulphur.

(6) *Scale* or other solid substances often accumulate in steam boilers, immediately over the hottest part of the furnace, and prevent the water from protecting the plates from the intense heat, whence the plates become softened and bag down, producing pockets that will hold one or more quarts of scale or other material; the metal forming these pockets becomes reduced in thickness, and eventually small holes appear, which let the water slowly out of the boiler and put the fire out, thus acting as safety valves. Explosions rarely occur from this cause.

(7) *An Explosion* of gas under the boilers might cause the boilers to be lifted high enough in their settings to sever the fittings from the boilers or to break the steam main pipe, especially when the pipe or fittings are made of cast iron.

A gas explosion may jar the boiler loose from its hangings and cause a disturbance that would produce various kinds of destruction, most any of which would likely cause an explosion of the boiler.

(8) *Low Water.* Plates may become overheated by allowing the water to get too low in the boilers, whence they become too weak to resist the pressure of steam in the boilers and are likely

GILL—BOILER EXPLOSIONS.

Plate 1. Wreck of the Boilers and Boiler House at the Henry Clay Colliery, Shamokin, Pa., Oct. 11, 1894.

to rupture, and if there is water enough in the boilers an explosion will follow.

It is very common to attribute all boiler explosions to this cause, but the experienced investigator seldom finds it to be the true cause of explosions. Collapsing of flues in two flue boilers, by allowing the water to get too low in them, is of common occurrence, yet disastrous explosions rarely occur from this cause.

(9) *Throwing* a safety valve wide open suddenly may cause an explosion, this has been proved by repeated experiments. Suddenly opening a large throttle valve may produce the same result.

The Shamokin Boiler Explosion.

The most extensive boiler explosion (so far as the number of boilers is concerned) that we have any record of, is the explosion that took place on the 11th of October, 1894, at the Henry Clay Colliery, at Shamokin, Pa.

I present some views, taken a few days after the explosion; the large view, Plate 1, was taken from a point immediately back of where the boiler house stood. It is apparent that the house was completely wrecked.

There were thirty-six boilers in the plant, and they were erected in twelve batteries of three boilers each. Twelve of the boilers at one side and fifteen at the other, making twenty-seven in all, exploded. The nine remaining boilers, centrally located, did not explode, but they were blown down and the brickwork demolished.

Six of the nine unexploded boilers have been re-set and are now in use.

As there were only six lives lost by it, the explosion was not as disastrous in this respect as many others on record. As examples, I will mention the explosion of a return tubular boiler in the Park Hotel, Hartford, Conn., in the spring of 1889, by which forty-seven lives were lost. The explosion of a boiler on a ferry-boat, "The Westfield," in New York harbor, in June, 1876, which caused the death of one hundred persons and the injury of a hundred more. The explosion of the boilers on a Mississippi river steamboat, in the spring of 1865, by which several hundred lives were lost. Many other examples might be given.

Plate 2—Shows a nest of the parts of nine boilers that were driven into the culm bank in front of the boiler house. One of these was driven over thirty-five feet into the bank.

Beyond where the men are seen standing may be seen the front end of three boilers being reset at about their original location. The square hole seen in one of the boilers was cut out to obtain samples of the iron.

Plate 3—Shows the engine house that contains the engines with the large rope wheels used for hauling cars up an incline plane. One of the boilers, after shooting up like a rocket, and passing over the hill, came down the front end foremost (the rear head missing), passed through the roof, struck the winding wheel and passed out at right angles through the end of the house, and landed at the foot of the plane a thousand or more feet away. The coal breaker may be seen a little below and beyond the engine house.

Plate 4—Shows parts of two boilers that were forced into the culm bank in front of the boiler house. The one in a horizontal position had one head and one ring off. It was driven its whole remaining length, forty feet, into the bank, the head end entering first. Part of the covering had been removed before this view was taken.

The other boiler may be seen in Plate 1, at the right-hand side, standing in almost a vertical position. This position is possibly due to a compound explosion.

Plate 5—Shows the end of part of a boiler, twenty-three feet long, and with one head intact, that was found fully embedded in a bank. Its position in the bank is parallel with its original setting, with its ends reversed, some two hundred feet or more from its former location, and some thirty or more feet below the level of the boiler house. This part of the boiler started backward till it reached the hillside, then turned and traveled in a direction at a right angle to its former position some two hundred feet or more; then turned again and shot down a hillside at an angle of about 45°; crossed a roadway and passed into the solid bank. There is also shown a strip of the boiler twenty-nine feet in length that was torn from it in a spiral course during its flight.

GILL—BOILER EXPLOSIONS.

Plate 5. Photographed by John L. Gill, 3d.

END OF PART OF BOILER THAT WAS FOUND EMBEDDED IN A BANK, SHAMOKIN, PA., OCT. 11, 1894.

GILL—BOILER EXPLOSIONS.

Plate 3. Photograph by J. L. Gill, 3d.

Engine House as it Appeared After the Explosion.

Plate 4. Photograph by J. L. Gill, 3d.

Two Boilers that were Driven into the Culm Bank, Shamokin, Pa., Oct. 11, 1894.

GILL—BOILER EXPLOSIONS.

Plate .2 Photograph by J. L. Gill, 3d.

A Nest of a Portion of Nine Boilers Driven into the Culm Bank in Front of the Boiler House, Shamokin, Oct. 11, 1894.

I think this was one of the most remarkable incidents of the disaster. This was a probable case of compound explosion.

A portion of one of the exploded boilers, over twenty-two feet in length, was blown over half a mile away, and I am informed that a part of another boiler, eleven feet in length, with one head, was blown one mile and a half away, and in a direction almost at right angles to the position it occupied when in its setting; this would indicate that the boiler was broken in two and upended before the explosion took place that sent it on its long journey. It would take too much of your time to tell of the many curious freaks that took place at the time of this explosion.

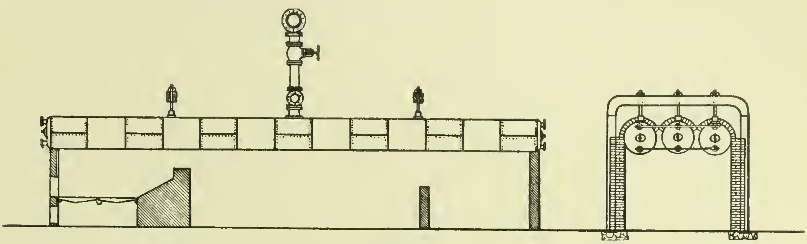

Fig. 1.

Figure 1 conveys a good idea of what the boilers were like and how they were sustained in place. The boilers were thirty-four inches in diameter and forty-three and one half feet in length. They were supported at the front end upon the iron front and at the rear end upon the brickwork, and they were suspended by two large bolts from crossbeams, one located at a distance equal to one fourth of its length from the front end, and the other at the same distance from the rear end.

The cast-iron crossbeams were supported at their ends upon cast-iron columns that were partly built around by the brickwork. Cast-iron washers with pockets in them to receive the square heads of the suspension bolts, were riveted on to the boilers. The pockets were open at one side to allow the bolts to enter sideways.

The boilers were all connected with each other through a steam main pipe, made of cast-iron; this pipe was twelve inches in diameter, and the iron was one inch in thickness. The boilers were connected with the steam-main through seven-inch nozzles.

This main was located immediatetly over the center of the boilers. The three boilers were connected with each other in front through nozzles with a manifold at the top, and again at the bottom. This made them practically one boiler, having three drums and one furnace.

It is apparent that when the boilers have been fired up, that they will be much hotter on the under side, which will cause the under side to expand more than the upper and cause it to take a curvilinear form, with the two ends raised upwards and the center bagged down. The weight of the heavy steam-main will add to this result.

It will appear that the boiler acts as a beam of the cantilever type. If the two ends are raised up from their bearings, the weight of the overhanging ends with the water contained therein acts as a lever, with the supporting casting as a fulcrum. This must cause a very great strain on the boiler, tending to break in two at this point. If the fire front holds the boiler down and prevents the drum from raising by the force of the expansion, the strain tending to break the drum in two must be much greater than if it was free to raise. The drums were only single riveted, yet there were no longitudinal ruptures, they were torn apart circumferentially, some of them through the rivet holes and others through the solid plate.

The Primary Cause of the Disaster.

The primary cause of the disaster will probably never be discovered, for the parts of the boilers were distributed over so large a territory that a satisfactory observation of the fractured parts could not be made, besides the stormy weather caused the parts to rust so much before they could be examined, that any examination would be very unsatisfactory. A theory has been advanced that poor material used in the construction of the boilers was the cause. I think this was not the case. While it is possible the material was not as good as was desirable, still it was a fairly good quality of laminated iron and would have withstood any ordinary strains that steam boilers are subjected to. The boilers certainly were called upon to resist very unusual strains.

There seem to be two plausible causes. *The first*, was low water in one of the boilers, for a part of one of the boilers was found that showed evidence of having been heated very hot (almost to a point of fusion).

It is quite possible that the valve between the water pipe and one of the boilers was closed, so that this particular boiler received no water and as soon as the water was low enough to allow the plates to be overheated, the boiler was ruptured and torn asunder by the pressure of steam from the other boilers; then the steam pressure in the other boilers was sufficiently reduced to allow the water contained in them to expand suddenly into steam, which would produce a force sufficient to explode the boilers, possibly one at a time.

The second cause. An explosion of gas under one of the boilers is a possible primary cause for the explosion. Explosions of gas under steam boilers are of frequent occurrence and of variable force. It is quite possible that the force exerted by an explosion of this kind was sufficient to raise the boiler and uncouple it from its hangings, when a reaction would cause the boiler to break in two (and at the same time to break the steam connection), after which an explosion must necessarily take place.

DISCUSSION.

Mr. James Christie.—As stated by Mr. Gill, the boilers at Shamokin were horizontal cylinders about forty-four feet long and were suspended by rods eleven feet from each end; hence they were not only subjected to internal pressure, but also to unequal strains at the top and bottom, due to this manner of mounting, and the latter strains must have been very great. In long boilers like these there is also unequal strain, due to the differences in temperature between the bottom and top, the latter in this case being open to the air.

Mr. Henrik V. Loss.—When I was connected with the Edge Moor Iron Company I remember to have made some experiments whereby we found that the differences between top and bottom strains in some cases might be as much as 5,800 pounds per square inch.

Mr. John Overn.—I examined the boilers at Shamokin on the day after the explosion and there was not a single case which showed any longitudinal strain. Each boiler shell was composed of thirteen plates, and all but one of those which exploded broke in the section to which the suspension rods were attached. By the use of a blower the heat under the boiler cylinders was made very great, while the top of the boilers was cool. After inspecting boilers for many years I have noticed that there are comparatively few exploded because of low water. The disturbance at Shamokin, I think, was due to unequal elongation on opposite sides of the boiler shells and to the very poor quality of iron used in their construction. (Mr. Overn then exhibited a sample of the boiler-shell iron, which he had brought back with him from Shamokin.)

Mr. Gill.—While I do not believe that this iron was of the very best quality, some samples of it were cut from the exploded boilers and tests made upon them for the coroner's jury, which gave fairly good results. I am of the opinion that the character of the material was not as bad as Mr. Overn would lead us to believe.

Mr. Overn.—I believe if these boiler shells had been made of steel instead of iron, that perhaps they would have been able to stand the strain imposed upon them.

Mr. Washington Jones.—Some ten or twelve years ago, in designing a lot of four boilers, I decided to use iron instead of steel, because we knew the quality of the former, and at that time the steel which we were able to get was of very doubtful strength. These boilers were five feet in diameter and six feet long and proved to be perfectly satisfactory, working well even at the present time.

HENRY W. DUNNE.

It is with feelings of deep regret that the members of the Engineers' Club of Philadelphia are called upon to note the death of their fellow member, Mr. Henry W. Dunne, which occurred suddenly in Philadelphia on the 26th of August, 1894.

Mr. Dunne was born in Philadelphia on November 1, 1856. He was a graduate of the Boys' Central High School of this city, and afterwards took a course in Civil Engineering. His first work in this field of labor was in connection with the Pennsylvania Railroad Company, whose service he entered as rodman in 1875. He served in that capacity for several years with the corps then engaged in the construction of new lines in the neighborhood of Philadelphia. When the line of the old Lancaster Turnpike between Philadelphia and Paoli was purchased, and what is now known as the Lancaster Avenue Improvement Company organized, Mr. Dunne was placed in charge of the rebuilding of the road, and upon its completion was appointed Superintendent. Subsequently when Mr. A. J. Cassatt was elected supervisor of the roads in Lower Merion Township, Mr. Dunne was appointed his deputy. He displayed ability and zeal in both positions and soon gained the respect and good will of the residents of the township.

On April 1, 1885, Mr. Dunne was appointed Superintendent of the New York, Philadelphia and Norfolk Railroad, with headquarters at Cape Charles, Va. The construction of this road had been completed and the line opened for through traffic but a few months prior to this time, and in entering upon his new duties Mr. Dunne had before him the task of perfecting the local organization, as well as carrying out the policy of the Company in a country where a railroad was an entire innovation, and where more or less prejudice existed against it. The successful manner in which all this work was performed bears additional evidence of the faithfulness with which his trust was executed. His conscientious devotion to the interests of the Company was always most marked.

Mr. Dunne was a man of unbounded enthusiasm and kindliness of heart, and his generous nature and genial temperament bound him closely to all his associates.

ABSTRACT OF THE MINUTES OF THE CLUB.

Regular Meeting, November 3, 1894.—President John C. Trautwine, Jr., in the chair. Ninety-eight members and visitors present.

The President announced that, as Secretary of the Association of Engineering Societies, he had issued to the prominent outstanding local and sectional engineering societies, including this Club, a circular letter soliciting co-operation in the Association's work, which at present consists entirely in the publication of the papers and proceedings of the societies in a monthly journal, issued by the Association, and embodying also an index of current technical literature.

The Association, formed twelve years ago, now embraces eight of the engineering societies of the country, with an aggregate membership of about 1200, and the *Journal* is issued monthly to these members and to a number of subscribers and exchanges.

It was believed that if the co-operation of the still outstanding societies could be secured, the result would be a journal of such character as to secure the subscription of every engineer who wished to keep abreast of the times, and the advertising patronage of all manufacturers and dealers in articles required by engineers, so that the cost of publication could be largely, if not wholly, covered by this source of revenue, and the assessments for publication purposes thus greatly reduced, if not entirely eliminated.

As pointed out in the circular letter referred to, the co-operation solicited does not necessarily involve the abandonment of the separate publication of the Club's Proceedings.

At present the Club is not asked to commit itself in the premises, but merely to confer with the Association as to what arrangements might be made.

Dr. Henry Leffmann presented a paper entitled "The Filtration of Public Water Supplies." This paper was discussed by Dr. Albert R. Leeds, Professor Walter L. Webb, and Messrs. Edward K. Landis, John C. Trautwine, Jr., Robert H. Cummings, John Birkinbine, James Christie, S. E. Moore, and W. C. Furber.

Mr. C. L. Prince exhibited some lantern-slides of the Tower Bridge, together with some views taken on the Club's excursion to Reading in June last.

A photograph received from Mr. O. M. Weand was exhibited, showing part of the west pier coffer-dam of the bridge now being erected across the Schuylkill at the Falls. This is the largest dam ever placed in the Schuylkill River above tide-water, and has successfully withstood three floods in the river since its construction. One 6-inch centrifugal pump empties the dam in ten hours, running at half capacity, and so tightly is the sheet-piling fitted to the rock that pumping is only necessary every five hours.

Business Meeting, November 17, 1894.—President John C. Trautwine, Jr., in the chair. Seventy-three members and visitors present.

The Secretary presented the following communication from the Association of Engineering Societies, with letters from the Secretary of the Association, dated October 26th and 31st, to more fully explain the matter:

PHILADELPHIA, October 26, 1894.

ENGINEERS' CLUB OF PHILADELPHIA.
MR. L. F. RONDINELLA, Secretary,
1122 Girard Street.

DEAR SIR:—For the mutual advantage of your Society and of the Association of Engineering Societies, we desire to call your attention to the methods of the latter, and to solicit your co-operation in its work.

The Association was organized in 1881, "in order to secure a joint publication of the papers and transactions of the participating societies."

At that time it embraced four societies, viz.: The Boston Society of Civil Engineers, the Western Society of Civil Engineers, the Civil Engineers' Club of Cleveland, and the Engineers' Club of St. Louis. Since then the Engineers' Club of Kansas City, the Engineers' Club of Minneapolis, the Montana Society of Civil Engineers, and the Civil Engineers Society of St. Paul have joined the Association. Our monthly *Journal*, since the appearance of its first number, in November, 1882, has steadily grown, until, in 1893, the twelfth annual volume comprised 657 pages of text and 211 pages of the Index of Current Technical Literature, which forms so important a part of the publication. This index is published monthly in the *Journal*, and is annually recompiled under one alphabetical arrangement, and reissued to each member of the participating societies. The expenses of publishing the *Journal* are met by quarterly assessments upon the several societies, in the ratio of their respective memberships.

We send you by this mail a number of sample copies of the *Journal*, so that your members may acquaint themselves with the character of the publication, both as to the material published and as to the manner of its presentation.

Please note that your membership in the Association need in no wise interfere with your separate publication of your own papers and proceedings; for after such papers have been printed for the *Journal*, any number of reprints can be made from the same type, and these reprints can be laid aside, to be furnished to you at any desired intervals, and bound in any desired form, as your own transactions, at no further cost than that of the additional paper, presswork and binding. This expense will, of course, be very light as compared with that of independent publication. Hence, if you already enjoy a considerable advertising patronage, most of this could be devoted to the payment of your assessments. You will notice, also, the very important point that by this method of co-operation your papers are given a very much wider circulation than is otherwise possible.

The Association will furnish, also, to any of the societies desiring them, advance copies of any papers submitted. Here, also, the additional expense on such papers as afterward appear in the *Journal* is only that of paper and presswork.

Every reader of engineering literature must have deplored the multiplication of separate engineering periodicals, and must have desired that as many as possible of these should be merged into one. It is this office which the Association of Engineering Societies has undertaken to perform.

The advantages of co-operation in the matter of publishing the papers of engineering societies are so manifest that it is scarcely necessary to enumerate them, but chief among them is that of economy; for with a given style of production, such work can, of course, be done more economically in large than in small quantities.

Thus far, however, the number of societies participating is inconsiderable when compared with the number of important local, State and sectional societies in the country, and hence, notwithstanding the economy due to the measure of co-operation already effected, our assessments at present amount to about $3.00 per annum for each member of the participating societies. For this each member receives, however, not merely the papers and transactions of his own society, but those of the other societies in the Association, together with the valuable Index of Current Literature already mentioned. It is believed that if all or most of the important societies join the Association, the assessments upon the members of the societies can be reduced, if not to zero, at least to a nominal figure, not only by reason of reduction of the cost of publication, but also and especially because a journal containing the transactions of

practically all of the important engineering societies of the country must command the subscription of every engineer who wishes to keep abreast of the times, and the advertising patronage of every enterprising furnisher of articles used by engineers.

If, therefore, such general co-operation can be effected, we confidently look to the attainment of much greater advantages than can be secured by the accession of any one society.

Please bring this matter to the attention of your members at the next meeting of your society, and get, if possible, some expression as to the desirability of your society's joining a general movement of this kind if it can be effected. This will enable our Board of Managers to issue a second circular letter to the societies not now in the Association, informing them how the matter is viewed by the other societies.

It is understood that any provisional expression of opinion sent to the undersigned, in response to this circular, will not commit your society in any way, but will merely indicate what will probably be the disposition of your society in case it is found practicable to unite the other outside societies in the movement.

Whatever action is to be taken should be taken before the beginning of the next fiscal year, and it is therefore hoped that this provisional expression of opinion will be rendered as soon as possible.

By order of the Board of Managers.

John C. Trautwine, Jr.,
Secretary.

Prof. Silas G. Comfort opened the discussion upon this matter by stating that, as Chairman of the Publication Committee, he had considered it his duty to the Club to carefully examine into the facts of this proposition as it would affect the interests of the Club and he would call the attention of the members to his opinion, as follows:

The By-Laws state, in Article IV, Section 6, that "The Publication Committee shall receive and examine all papers presented to the Club, and accept for publication such as they may approve, and shall publish the same quarterly, with a record of the procedings of the Club." We could not, therefore, do away with the separate publication of our papers without violating or first amending the By-Laws.

The Western Society of Engineers, at its August meeting, received a report from a special committee, recommending that the Western Society should withdraw from the Association of Engineering Societies, because the assessment for the current year had been $648.00, and would be $525.00 for the balance of the year, making a total expense of $1,173.00, and that up to date only one paper had appeared in the *Journal* of the Association. They believed it would be to the best interests of their society to publish their papers as soon after presentation as possible, in a periodical of their own. This report was accepted, and the Western Society decided to give provisional notice of its withdrawal, to be acted upon finally at the December meeting.

In passing, Professor Comfort called attention to the statement which appeared in a recent editorial in *Engineering News*, making comparisons between another engineering society and ours as to the influence which the cost of issuing separate *Proceedings* had upon the financial conditions of the two clubs, in which the facts with reference to our Club were stated incorrectly, and would be apt to leave a wrong impression on the minds of readers.

Regarding our own Proceedings, the present Publication Committee, in accordance with the often expressed desire of the Club, has made a special effort to have the

papers printed and issued promptly, and in no case during the past year have the numbers been sent out later than the month provided for their issue. This month's number will be sent out in a few days. If we were to send our papers for publication in the *Journal of the Association of Engineering Societies*, only a small proportion of them could be published in that *Journal*, and as they would have to take their turn with those accepted from other societies, they would probably not be printed for a considerable time after their presentation.

The net cost of our PROCEEDINGS to the Club, according to the last Annual Report of the Board of Directors, was $30.57. But putting a very moderate estimate on the value of the magazines which were received in exchange, the Club actually received during the year a net value of over $250. The periodicals that we have in our reading-room through exchange constitute one of the most valuable features of our library, and if we discontinued our publication we probably could not afford to purchase all of them.

With regard to transferring advertisements, as most of those which appear in our PROCEEDINGS are received as a benefit to the Club primarily, I doubt whether it would be possible to induce the advertisers to transfer them to another journal.

I therefore think it would be extremely unwise to discontinue the publication of our PROCEEDINGS, or to join the Association of Engineering Societies for the purpose of having some of our papers published in its *Journal*, and paying a considerable assessment for the *Journal* itself. We should keep up the outside reputation which we have made through our publication.

Mr. John C. Trautwine, Jr. (having left the chair before this matter was presented), remarked that, recognizing the delicacy of his position, he wished to avoid anything like an appeal to the members present, but that he felt it due to the Association and to himself, as a member of the Club, to take exception to Professor Comfort's estimate of the financial status of the proposition.

As stated in the letter of invitation, it was quite possible that the Association, in the event of general co-operation on the part of the outstanding societies, might see its way clear to make a material reduction of the assessments, even at the start.

Furthermore, in view of the monthly issue of the *Journal* and of its much larger circulation, it would offer to its advertisers, if none but our own Club were added to its list, about twelve times the publicity given by the Club PROCEEDINGS. It seemed quite probable, therefore, that a committee of investigation would find it easy to secure sufficient advertising patronage to net the Club (even under the Association's present allowance of 50 per cent. of such receipts), as much as at present or more.

Altogether, it was believed that it might be found practicable to secure to our members the advantage of a monthly journal containing the papers of many other societies besides our own and the Association's Index to Current Technical Literature, together with a vastly greater circulation of our own papers, at little or no increase of the present cost.

Finally, as pointed out in the letter of invitation, the participation of our Club in the work of the Association would not necessarily involve the abandonment of our independent publication.

MR. Charles L. Prince called attention to the fact that the personal pride in the success of our PROCEEDINGS, which was felt by our Publication Committee and

those who presented papers, would be lacking in the case of the *Journal* of the Association, and that consequently if we joined that Association we should be simply one of many, and our papers would be sandwiched in wherever there might be room. The record of this year's PROCEEDINGS is extremely creditable to the Club, and there would seem to be no valid or strong argument for joining the Association.

Mr. John Birkinbine stated, that at the meeting two weeks ago, he took ground that this matter should be referred to our Board of Directors, to be acted upon by them or their Publication Committee, but that now, as it was before the Club, we should consider it in a broad, business-like manner. In doing this we should think of Mr. Trautwine simply as Secretary of the Association, and in doing his official duty we must not think that he is acting for or against the Club. Sometime since the Association was not in a most healthy condition, and Mr. Trautwine's services were obtained, and he has since been trying to improve it. We should not say now that we will not have anything to do with the proposition in a way that would publicly injure a project in which one of our members is so closely interested.

Mr. Trautwine: As a member of the Club I share in the just pride in our own PROCEEDINGS, but think that the further consideration suggested by Mr. Birkinbine might show advantages in favor of our joining the Association, which would more than compensate for the discontinuance of our own publication.

A motion was then made and seconded that three delegates from the Club, including the Chairman of the Publication Committee, be appointed to meet the Board of Managers of the Association of Engineering Societies for conference on this subject.

Mr. George A. Bullock, in discussion on this motion, remarked that it was plain from what had already been said that a majority of the members present did not wish to join this Association, and he thought if delegates were appointed they should also be instructed how to act. If the *Journal* of the Association was in need of financial assistance he considered that it might be wise for the Club or its individual members to subscribe for it, but he did not approve of relinquishing our own publication.

The motion was then put and lost.

Prof. Comfort then presented the following: *Resolved*, That, after careful consideration, the Engineers' Club of Philadelphia does not deem it advisable to accept the proposition of the Association of Engineering Societies, presented this evening, nor to relinquish the separate publication of its own PROCEEDINGS.

This resolution was adopted.

Resignations of active membership were presented and accepted from the following: Messrs. A. C. Cunningham, H. F. DePuy, H. M. Fuller, John R. Hoffman, W. H. Norris and George L. VanZandt.

Mr. George H. Bullock made some informal remarks on some recent "Highway Improvements in Philadelphia."

BUSINESS MEETING, December 1, 1894.—President John C. Trautwine, Jr., in the chair. Sixty-four members and visitors present.

The Tellers reported the following gentlemen elected to active membership: Messrs. Arthur Gregg Singer, George S. Barrows and Francis J. Boas.

The Special Committee, appointed to consider Mr. Elmer L. Corthell's proposition for the formation of a society with the above title, presented its report, expressing

the opinion that, while the objects of the organization were eminently commendable, they could be accomplished by the national societies of each country. The publication of approved domestic and foreign professional papers is already done to a large extent by the Institution of Civil Engineers, in England, in their Abstracts of Papers in Foreign Transactions and Periodicals, and by the American Association of Engineering Societies, in their Index to Current Technical Literature. The Committee, therefore, did not approve of the suggested organization of the Institute, nor consider it within its province to submit the details for a constitution.

This report was adopted as the sense of the Club.

The Secretary read a memorial, prepared by Messrs. A. J. Cassatt and Gratz Mordecai, on our deceased member, Henry W. Dunne.

NOMINATIONS FOR OFFICERS FOR 1895.

Office.	Nominee.	Proposer.	Seconder.
President,	George S. Webster.	George T. Gwilliam.	L. Y. Schermerhorn.
Vice-President,	John L. Gill, Jr.	Silas G. Comfort.	W. B. Riegner.
Secretary,	L. F. Rondinella.	James Christie.	R. A. Cummings.
Treasurer,	George T. Gwilliam.	James Christie.	W. C. Cranmer.
Director,	W. C. Furber.	W. B. Riegner.	F. H. Lewis.
"	Rudolph H. Klauder.	F. C. Dunlap.	R. A. Cummings.
"	Henry Leffmann.	R. A. Cummings.	W. C. Furber.
"	Edgar Marburg.	H. W. Spangler.	W. B. Reigner.

The President appointed on the Nominating Committee, to fill any vacancies that might occur in the list of nominations, as provided by the By-Laws, Messrs. Silas G. Comfort, John Birkinbine, Max Livingston, Henrik V. Loss and Henry C. Lüders.

Mr. Frederick H. Lewis read a paper on "Specifications for Portland Cements and for Cement Mortars," in which he described in detail the reasons for and against the specifications proposed, which were sent out in abstract with the notice for the last meeting.

The paper was followed by a general discussion on the cement question, which was participated in by Messrs. Lesley, Humphreys, Cummings, Webster and others.

REGULAR MEETING, December 15, 1894.—President John C. Trautwine, Jr., in the chair. Sixty-six members and visitors present.

Mr. John L. Gill, Jr., presented a paper on "Boiler Explosions." The subject was discussed by Messrs. James Christie, Henrik V. Loss, John Overn and Washington Jones.

Mr. Carl G. Barth read a paper on "The Principles of the Calculus in a New Light," which he illustrated profusely by examples on the blackboard. An abstract of this paper was sent out with the notice for the meeting.

At the conclusion of Mr. Barth's remarks, Mr. Henrik V. Loss made some comments on the comparative advantages of the usual method of calculus and that proposed, and, upon motion, further discussion was deferred until a future meeting, on account of the lateness of the hour.

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

Regular Meeting, November 17, 1894.—Present: President John C. Trautwine, Jr., Directors W. B. Riegner, Henry J. Hartley, John L. Gill, Jr., Edward K. Landis, Silas G. Comfort, Charles L. Prince, and the Secretary and the Treasurer.

The Treasurer's Report showed:

Balance from September	$262 30	
Amount received during October	353 02	
		$615 32
Amount expended during October		423 91
Balance, October 31, 1894		$191 41

The Treasurer was instructed to send a letter to all members indebted to the Club, asking that their dues be paid before the end of the year, and a special registered letter to those who, if still delinquent, would be dropped at the end of the year in accordance with the By-Laws.

The Publication Committee reported that after further interviews with Mr. Alexander, Superintendent of Mails of Philadelphia, it appeared that he would only approve the admission of our Proceedings as second class mail matter if some individual was specified on the title-page, and would sign the application papers as publisher, and that the Committee had therefore thought the name of the Secretary was the proper one to appear, and that they had therefore prepared a new proof of title-page in accordance with this plan, which was submitted to the Board. This title-page was approved.

The House Committee reported that a gas cock could be put in the main supply pipe to turn off all jets in the meeting room at one time, at an expenditure of about $25. At the Secretary's suggestion, the Committee was authorized instead to have a rocker arm cock put in the drop pipe at the top of each chandelier, with chains to turn the same on and off.

Regular Meeting, December 15, 1894.—Present: President John C. Trautwine, Jr., Vice-Presidents James Christie and A. Falkenau, Directors W. B. Riegner, John L. Gill, Jr., Edward K. Landis, Silas G. Comfort and Charles L. Prince, and the Secretary and the Treasurer.

The President reported that he would call a Special Meeting of the Board for the afternoon of January 5th, to consider the Annual Reports of the Board and the Treasurer, so that they might be printed and sent out with the Notice for the Annual Meeting.

The Treasurer's monthly report showed:

Balance from October	$191 41	
Amount received during November	214 10	
		$405 51
Amount expended in November		323 99
Balance, November 31, 1894		$81 52

The Treasurer also reported that he had sent a letter, the form of which he read, to fifty-eight members who were indebted to the Club for this year's dues, and had sent another form, which he also read, by registered mail to thirty-one members who were two years or more in arrears, and would be dropped from the roll under the By-Laws, unless payment was made before January 1st. Upon motion, the Treasurer was instructed to reply to the answers received to the registered letters, quoting the second paragraph of Article VIII of the By-Laws, stating that the Board and the Treasurer had no option but to see that it was carried out.

The Secretary reported that all the nominees for office had signified their willingness to accept if elected.

The Secretary presented a letter from Mr. S. Annear, offering to publish the Directory of the Club for 1895, like that which he got up last last year. The Secretary was instructed to engage him to do this.

Upon motion, the President was authorized to represent the Board in the appointment of auditors and tellers.

Upon motion, the salary of the Secretary was fixed at $20 per month for 1895, and the other salaries for that year were made the same as for 1894.

Upon motion, the chair appointed Messrs. Comfort, Christie and Gill as a Committee to prepare the Annual Report of the Board of Directors to be presented at the Special Meeting of January 5th.

CONTRIBUTIONS TO THE LIBRARY.

From October 15 to December 15, 1894.

From American Society of Irrigation Engineers.

Annual of the Society for 1892–93.

From Arata Hamao.

The Imperial University Calendar, 1893–94.

From Department of Internal Affairs of Pennsylvania.

Annual Report of the Secretary, 1893.
Part I—Land Office. Boundary Lines. State Weather Service.
Part II—Assessments. Taxes.
Part III—Industrial Statistics.
Part IV—Railroads, Canals, Telegraphs and Telephones.
Part V—Reports of Inspectors of Coal Mines.

From General Compressed Air Company.

Rapid Transit in New York.

From Institution of Civil Engineers, London.

Abstracts of Papers in Foreign Transactions and Periodicals.
Concrete Bridge at Munderkingen—Leibbrand.
Corrosion of Metals—Andrews.
Discharge from Catchment-Areas—Stent.
Estuaries—Partiot.
Lighthouse Refractors—Stevenson.
Railway Work in Argentina—Forrest.
Refrigerating Machines—Gale.
Ship Slipways—Beer.
Strength of Cement Concrete—Bruce.
Training of Rivers—Vernon-Harcourt.

From Edward H. Keating.

Annual Report of the City Engineer of Toronto, 1893.

From New England Roadmasters' Association.

Proceedings, 1894.

From Pennsylvania Geological Survey.

Appendix to Grand Atlas.

From William H. Pratt.

Report of Geological Survey of New Jersey, Vol. II, Part I, 1889. Vol. II, Part II, 1890.
Report of United States Coast Survey, 1864, 1869–77.
Report of United States Coast and Geodetic Survey, 1878–85.
Report of United States Geological Survey, 1881–84.

From Pullman Palace Car Company.

The Strike at Pullman.

From State Board of Health of Massachusetts.

Twenty-fifth Annual Report, 1893.

From John C. Trautwine, Jr.

Text-Books on Roads and Pavements—Spalding.

From United States Coast and Geodetic Survey.

Report 1892, Part II.

From United States Navy Department.

Annual Report of the Chief of the Bureau of Steam Engineering, 1894.

From Hon. D. W. Voorhees.

Bulletins:
- Committee on Finance.
- Opinions of Collectors of Customs Concerning ad valorem and Specific Rates of Duty on Imports.
- Replies of Importers, Manufacturers and Others to Tariff Inquiries.
  - Schedule A, Chemicals, Oils and Paints. Three Vols.
  - Schedule C, Metals and Manufacturers of. Ten Vols.
  - Schedule D, Woods and Manufacturers of. Ten Vols.
  - Schedule E, Sugar. Two Vols.
  - Schedule F, Tobacco and Manufactures of. Three Vols.
  - Schedule G, Agricultural Products and Provisions. Six Vols.
  - Schedule H, Spirits, Wines and Other Beverages. Two Vols.
  - Schedule I, Cotton and Manufactures of. Three Vols.
  - Schedule J, Flax, Hemp and Jute and Manufactures of. Two Vols.
  - Schedule K, Wool and Manufactures of. Two Vols.
- The Sugar Schedule in the Tariff Bill of 1894.

From William R. Webster.

Observations on the Relations Between the Chemical Constitution and Ultimate Strength of Steel.